286046 P-1440

COMPRESSED GAS ASSOCIATION
4221 Walney Road, 5th Floor ■ Chantilly, VA 20151-2923
(703) 788-2700 ■ FAX: (703) 961-1831 ■ E-mail: cga@cganet.com ■ Web Site: www.cganet.com

RSPA-02-12660-4

April 13, 2004

Mr. Edward Mazzullo, Director
Office of Hazardous Materials Standards
U.S. Department of Transportation
Research and Special Programs Administration
400 7th Street, SW
Washington, DC 20590

Dear Mr. Mazzullo,

The Compressed Gas Association (CGA), founded in 1913, represents over one hundred twenty member companies' world wide in the development and promotion of safety standards and safe practices in the industrial gas industry. The Association represents all facets of the industry – manufacturers, distributors, suppliers, and transporters. Through the committee system CGA creates technical specifications, safety standards, training and educational materials; and also works with government agencies to formulate responsible regulations and standards and to promote compliance with these regulations.

CGA members produce, market, and distribute industrial gases and cryogenic liquids such as acetylene, carbon dioxide, ethylene, hydrogen, nitrogen, nitrous oxide, and oxygen as well as various specialty gases, many classified as poison gases. Accordingly our members have a strong interest in domestic and international regulations governing these products and the containers in which they are shipped.

CGA publication S-7 – 1996 *Method for Selecting Pressure Relief Devices for Compressed Gas Mixtures in Cylinders*, is referenced in 49 CFR 171.7 and 173.301. The standard provides a method to assign the appropriate pressure relief deviceto gas mixtures based on the flammability, toxicity, state of the gases, and corrosiveness of the final mixture. As it is referenced in 49 CFR, it thereby carries a regulatory imperative.

The CGA committee responsible for managing this publication is the Pressure Relief Devices Committee and since the publication ofthe 1996 edition, CGA S-7 has been revised. Attached to this request is a full listing of all the changes made to the 1996 edition.

The changes to the 1996 edition are largely editorial and reformatting. The one significant change is to align the use of pressure relief devices on cylinders containing silane mixtures with the changes made in CGA S-1.1 – 2003 *Pressure Relief Device Standards–Part 1–Cylinders for Compressed Gases.* The change in CGA S-1.1 – 2003 makes optional the requirement for pressure relief devices on cylinders of silane that are less that 50 liters water capacity and filled to less that 1250 psig at 70 °F.

CGA respectfully requests that the 2003 edition of CGA S-7 be adopted in its entirety by the Department of Transportation (DOT), added to the sections previously listed and thereby carry the same regulatory imperative as CGA S-7 – 1996.

Please contact me with any questions you may have or for any assistance we can provide to achieve approval of our request.

Sincerely,

COMPRESSED GAS ASSOCIATION, Inc,

Roger A Smith

Roger A. Smith
Technical Director

RS/rs
Enclosures:
S-7 – 1996 (4 copies)
S-7 – 2003 (4 copies)
List of changes to the 1996 edition

cc: Mr. Charles Hochman – DOT
Ms. Hattie Mitchell – DOT
Mr. Mark Toughiry – DOT
Ms. Sandra Webb – DOT
Mr. Carl T. Johnson, President CGA (letter only)

PCS	Section	Original Wording (1996 edition)	Changed Wording (2003 edition)	Reason for Change
3419	1.7		Added new text Section 1 as last paragraph: The continued use of previously recognized and installed devices is not restricted by this edition of the standard. However, if a pressure relief device is replaced, the new device shall meet the requirements of this standard.	To allow a device proven to be adequate and previously recommended by this standard to continue to be used. It would also provide continuity between various issues of the same publication.
3699	Examples 6 & 7		Added new diamond after the third diamond as follows: Does mixture contain silane at a partial pressure ≤1250 psig at 70 °F? Yes = No pressure relief device required. If one is used a CG-4 is recommended. (Please note: Example numbers changed from 6 & 7 to 7 & 8 in the 2003 edition)	Silane when filled to a pressure of 1250 psig at 70F will nominally have a mass of 12,000 grams. This equates to a fill density of 12,000 grams/43,800 cc = 0.2739 in a 43.8 liter cylinder. It is recommended that a fill density of 0.274 be used. In CGA S-1.1, the recommendation is made to allow cylinders filled with pure silane to have the pressure relief device optionally omitted if the settled pressure is less than 1250 psig at 70 F. This proposed change would provide harmonization in CGA S-7 for silane mixtures at the same fill density. Mixtures filled to the same fill density can have the pressure relief device optionally omitted as agreed to for pure silane. Silane was previously packaged without a pressure relief device at pressures below 300 psig. A fourth decision diamond in the CGA S-7 flowchart is recommended and will be included in all the examples noted in CGA S-7.

PCS	Section	Original Wording (1996 edition)	Changed Wording (2003 edition)	Reason for Change
5746	6	[2] *Regulations for the Transportation of Dangerous Commodities by Rail*, Transport Canada. Supplies and Services Canada, Canadian Publication Centre, Ottawa KIA S59 CANADA.	[2] *Transportation of Dangerous Goods Regulations*, Transport Canada, Canadian Government Publishing, Public Works and Government Services Canada, Ottawa, ON K1A 0S9, Canada. www.tc.gc.ca	The reference to the Transport Canada regulations in section 6 [2] is out of date.

CGA S-7—2003

METHOD FOR SELECTING PRESSURE RELIEF DEVICES FOR COMPRESSED GAS MIXTURES IN CYLINDERS

THIRD EDITION

COMPRESSED GAS ASSOCIATION, INC.
4221 Walney Road, 5th Floor
Chantilly, VA 20151
Phone: 703-788-2700
Fax: 703-961-1831
E-mail: cga@cganet.com

PLEASE NOTE:

The information contained in this document was obtained from sources believed to be reliable and is based on technical information and experience currently available from members of the Compressed Gas Association, Inc. and others. However, the Association or its members, jointly or severally, make no guarantee of the results and assume no liability or responsibility in connection with the information or suggestions herein contained. Moreover, it should not be assumed that every acceptable commodity grade, test or safety procedure or method, precaution, equipment or device is contained within, or that abnormal or unusual circumstances may not warrant or suggest further requirements or additional procedure.

This document is subject to periodic review, and users are cautioned to obtain the latest edition. The Association invites comments and suggestions for consideration. In connection with such review, any such comments or suggestions will be fully reviewed by the Association after giving the party, upon request, a reasonable opportunity to be heard. Proposed changes may be submitted via the Internet at our web site, www.cganet.com.

This document should not be confused with Federal, state, provincial, or municipal specifications or regulations; insurance requirements; or national safety codes. While the Association recommends reference to or use of this document by government agencies and others, this document is purely voluntary and not binding.

A listing of all publications, audiovisual programs, safety and technical bulletins, and safety posters is available via the Internet at our website at www.cganet.com. For more information contact CGA at Phone: 703-788-2700, ext. 799. E-mail: customerservice@cganet.com.

Docket 01-23
Pressure Relief Devices Committee

NOTE—Technical changes from the previous edition are underlined.

NOTE—Appendices A and B (Normative) are requirements.

NOTE—Appendix C (Informative) is for information only.

THIRD EDITION: 2003
SECOND EDITION: 1996
FIRST EDITION: 1989

4221 WALNEY ROAD, 5TH FLOOR, CHANTILLY, VA 20151
Printed in U.S.A.

Contents **Page**

Figures

Examples

Appendices

This page is intentionally blank.

1 Introduction

This publication presents a method for selecting pressure relief devices for compressed gas mixtures packaged in cylinders having water capacities of 1000 lb (454 kg) or less (see 49 CFR 173.301(f)) and Department of Transportation (DOT) 3AX, 3AAX, and 3T cylinders having water capacities over 1000 lb (454 kg) that comply with the specifications, charging, and maintenance regulations of the DOT or the corresponding specifications and regulations of Transport Canada (TC) [1, 2].[1]

The task has been much more difficult than arriving at a method for determining the appropriate valve outlet connections for gas mixtures. For the latter, as described in CGA V-7, *Standard Method of Determining Cylinder Valve Outlet Connections for Industrial Gas Mixtures*, mixture rating numbers are assigned to the various compressed gases based on the physical properties of the gases, i.e., flammability, toxicity, state of the gas, and corrosiveness [3]. The higher the mixture rating number (1 through 6), the more influential that gas becomes in determining the outlet connection for the mixture in which that gas is a component.

Valve outlet connection assignments are broadly separated into connections for groups of gases having similar properties such as high and low pressure, flammability, corrosivity, toxicity, and inertness. Since 1978 this system has proven satisfactory in avoiding hazardous connections.

The physical characteristics of a mixture consisting of several pure gases could be dramatically different depending on the concentration of each gas in the mixture. Depending on these concentrations, a mixture could be flammable or nonflammable, toxic or nontoxic, corrosive or noncorrosive. Since the mixture is released to the atmosphere when the relief device functions, the characteristics of the escaping gas mixture must be well defined.

It was concluded that a method would have to be established for assigning the proper relief device for each mixture, just as is done for pure gases in CGA S-1.1, *Pressure Relief Device Standards—Part 1—Cylinders for Compressed Gases* [4]. To use this method, the proper FTSC Code must be determined (see Appendix A). In some cases, determining the proper FTSC number is straightforward. However, in other cases the appropriate FTSC number is not as obvious, and in most cases this determination is the responsibility of the gas mixture producer. It must be understood that some of the considerations made in determining the selection of the pressure relief device used in this publication are based on experience.

The method outlined in the publication is designed to handle the proliferation of mixtures entering the commercial market.

The continued use of previously recognized and installed devices is not restricted by this edition of the standard. However, if a pressure relief device is replaced, the new device shall meet the requirements of this standard.

2 Scope

This method is applicable to the determination of the proper pressure relief device to use with cylinders of less than 1000 lb (454 kg) water capacity, as well as DOT 3AX, 3AAX, and 3T (TC3AXM, 3AAXM, 3TM) cylinders of water capacities over 1000 lb (454 kg) containing compressed gas mixtures.

This method is limited to those compressed gas mixtures with known flammability, toxicity, state, and corrosivity. In addition, the DOT/TC rating and dimensions of the cylinder and the final pressure must be known.

For the selection of pressure relief devices for a single component compressed gas, see CGA S-1.1 [4]. For multicomponent compressed gases (mixtures), the method for selection of relief devices in this publication should be used. Where a mixture is predominantly made up of a single component in a mixture, the gas producer shall determine whether the properties of this mixture dictate it being treated as a single component compressed gas or a gas mixture.

[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3 Definitions

For the purpose of this standard, the following definitions apply.

3.1 Algorithm
A series of formatted questions that when answered in sequence will result in the selection of one or more pressure relief devices.

3.2 Blanketing or pressurizing
The pressurization of the vapor space above a liquefied gas or liquid for the purpose of liquid withdrawal.

3.3 Charged pressure
The final fill pressure at 70 °F (21.1 °C).

3.4 Compressed gas
Any material that exerts in a container an absolute pressure of at least 40.6 psia (280 kPa) at 68 °F (20 °C).[2]

3.5 Gas mixture
The purposeful combination of two or more commodities resulting in a compressed gas.

3.6 Producer
The site where the compressed gas mixture is packaged into cylinders and the personnel who perform the work.

3.7 Lethal Concentration Fifty (LC_{50})
A concentration of a substance in air for which exposure for a specified length of time is expected to cause the death of 50% of the entire defined experimental animal population. (See CGA P-20, *Standard for the Classification of Toxic Gas Mixtures* [6]).

3.8 Hazard zone A
A material with a toxicity LC_{50} less than or equal to 200 ppm.

3.9 Hazard zone B
A material with a toxicity LC_{50} greater than 200 ppm and less than or equal to 1000 ppm.

3.10 Hazard zone C
A material with a toxicity LC_{50} greater than 1000 ppm and less than or equal to 3000 ppm.

3.11 Hazard zone D
A material with a toxicity LC_{50} greater than 3000 ppm and less than or equal to 5000 ppm.

4 Types of pressure relief devices

Types of pressure relief devices are designated as follows:

4.1 Type CG-1

A rupture disk.

4.1.1 Limitations

Since this is a pressure-operated device designed to release the entire content of the container, there is no way of preventing the complete release of the content, either as a result of normal functioning or premature rupture of the device.

---

[2] kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per CGA P-11, *Metric Practice Guide for the Compressed Gas Industry* [5].

4.2 Type CG-2

A fusible plug using a fusible alloy with yield temperature not over 170 °F (76.7 °C) or less than 157 °F (69.4 °C). Nominal yield temperature is 165 °F (73.9 °C).

4.2.1 Limitations

Since this is a thermally operated device, it does not protect against overpressure from improper charging practices. This device releases the entire lading of the container when it functions. This device is limited to use on cylinders of 500 psig (3450 kPa) service pressure or less. This device may be used in higher service pressure cylinders provided that the product pressure does not exceed 500 psig (3450 kPa) at 68 °F (20 °C) and the device type is mandated by this standard or TC regulations.

4.3 Type CG-3

A fusible plug using a fusible alloy with yield temperature not over 224 °F (106.7 °C) or less than 208 °F (97.8 °C). Nominal yield temperature is 212 °F (100 °C).

4.3.1 Limitations

Same as for Type CG-2 (see 4.2.1).

4.4 Type CG-4

A combination rupture-disk/fusible-plug device using a fusible alloy with yield temperature not over 170 °F (76.7 °C) or less than 157 °F (69.4 °C). Nominal yield temperature is 165 °F (73.9 °C).

4.4.1 Limitations

Since this device is a combination device, it requires both excessive pressure and temperature to cause it to operate. This device will not function due to pressure unless the fusible metal is melted out first. Such a combination device cannot prevent an improperly filled (overfilled) cylinder from rupturing due to hydrostatic pressure at room temperature or any temperature below the melting temperature of the fusible metal, as will devices that contain only a rupture disk (CG-1). There is no way of preventing the complete release of the content when this device functions.

4.5 Type CG-5

A combination rupture-disk/fusible-plug device using a fusible alloy with yield temperature not over 224 °F (106.7 °C) or less than 208 °F (97.8 °C). Nominal is 212 °F (100 °C).

4.5.1 Limitations

Same as Type CG-4 (see 4.4.1).

4.6 Type CG-7

A pressure relief valve.

4.6.1 Limitations

This device maintains the pressure in the container at a limit as determined by the set pressure of the valve and thus does not protect against rupture of the container when the application of heat weakens the container to the point where its rupture pressure is less than the operating pressure of the device.

WARNING: *Pressure relief devices may not prevent rupture of a cylinder under all conditions of fire exposure. When the heat transferred to the cylinder is localized, intensive, and remote to the relief device, or where the fire builds extremely rapidly, such as in an explosion, and is of very high intensity, the cylinder may weaken sufficiently to rupture before the relief device operates or while it is operating.*

5 Description of method and procedures

5.1 Algorithm

The lgorithm has been designed to assist the gas mixture producer to quickly and correctly determine the appropriate pressure relief device(s) for gas mixtures. The algorithm is shown in Figure 1 (US) and Figure 2 (SI). Application of the algorithm is illustrated for selected gas mixtures in Examples 1-12.

5.2 Responsibility for selection of the pressure relief device

The responsibility for the selection of the pressure relief device lies with the gas mixture producer. Although the algorithm does permit a degree of flexibility in the selection of the relief device for some cylinders, the flammability, toxicity, state, and corrosivity of the mixture must be determined first. Appendix A provides the definitions of the FTSC codes. Appendix B lists the codes for most of the gases that are commonly used in mixtures.

5.3 Guidelines for use of the algorithm

The following guidelines and constraints govern the use of the algorithm:

- The final mixture properties, i.e., flammability, toxicity, state of the gas, corrosiveness, and final pressure are known by the gas mixture producer.
- The producer shall determine the mixture's flammability. As used in the algorithm, "Flammable" means having an "F" rating of 2, 3, or 5.
- The producer shall determine the mixture's toxicity. As per DOT (49 CFR 173.115), the toxicity of the mixture can be calculated (see CGA P-20 for additional details regarding mixture toxicity calculations) from the concentrations and toxicity of the components as follows [6]:

$$LC_{50,mix} = \frac{1}{\sum_{i=1}^{n} \frac{Concentration_i}{LC_{50,i}}}$$

Where:

n = the number of toxic components

$Concentration_i$ = the concentration of the i^{th} toxic component, expressed as a decimal fraction of the whole, e.g., 0.05 for a 5% mixture and 5×10^{-6} for a 5 ppm mixture. This number is dimensionless.

$LC_{50,i}$ = The LC_{50} of the i^{th} toxic component, in ppm

$LC_{50,mix}$ = the LC_{50} of the mix, in ppm

For a mixture with a single toxic component, this simplifies to:

$$LC_{50,mix} = \frac{LC_{50,\text{toxic component}}}{Concentration_{\text{toxic component}}}$$

- As used in the algorithm, "Corrosive" means having a "C" rating of 1 or greater.
- Other definitions conform with those of DOT or TC if applicable.
- Pressurization of the vapor space above a condensed liquid for the purpose of withdrawal does not constitute a gas mixture.

- If a 110% fill is authorized, only the CG-1 device is allowed.
- When the CG-2 device is indicated, it allows use of the CG-3 device where the final mixture properties permit. Likewise when the CG-4 device is indicated, the CG-5 device can be used where the final mixture properties permit.

NOTE—The decision of whether the CG-2 or CG-3 is used as well as whether the CG-4 or CG-5 is used shall be made by the gas mixture producer as authorized by the latest edition of CGA S-1.1 based on the producer's classification of the final mixture according to its properties [4].

- Where two or more types of pressure relief devices are indicated, only one of them is required. Care should be taken that the selection made conforms to all requirements in 49 CFR and CGA S-1.1 [1, 4]. For example, see CGA S-1.1 regarding the requirements for relief devices at both ends of the cylinder if the cylinder length exceeds 30 in (762 mm) [4].

5.4 Procedure for assigning a pressure relief device for a mixture

With an understanding of the guidelines in 5.3, the procedures below shall be followed to assign a pressure relief device for a mixture (see Appendix C for a worksheet format):

a) In the worksheet, list the components and concentration thereof in the proposed gas mixture in the first two columns;

b) Enter the FTSC code for each mixture component directly from Appendix B in the next four additional columns;

c) Add the LC_{50} in the last column from Appendix B, if available;

d) Verify that the DOT/TC rating and dimensions of the cylinder to be filled as well as the final pressure of the mixture are compatible with each other and are in compliance with pertinent regulations contained in 49 CFR 173.301(a)(8) [1];

e) Calculate the toxicity (T) of the mixture as described in 5.3 and assign F, S, and C codes based on experience and the properties of the components of the mixture;

f) Using the mixture's FTSC code established in step e), answer each question, beginning at the "Start" of the algorithm, until a determination of the proper pressure relief device is accomplished; and

g) Size the pressure relief device in accordance with the requirements of the latest edition of CGA S-1.1 [4].

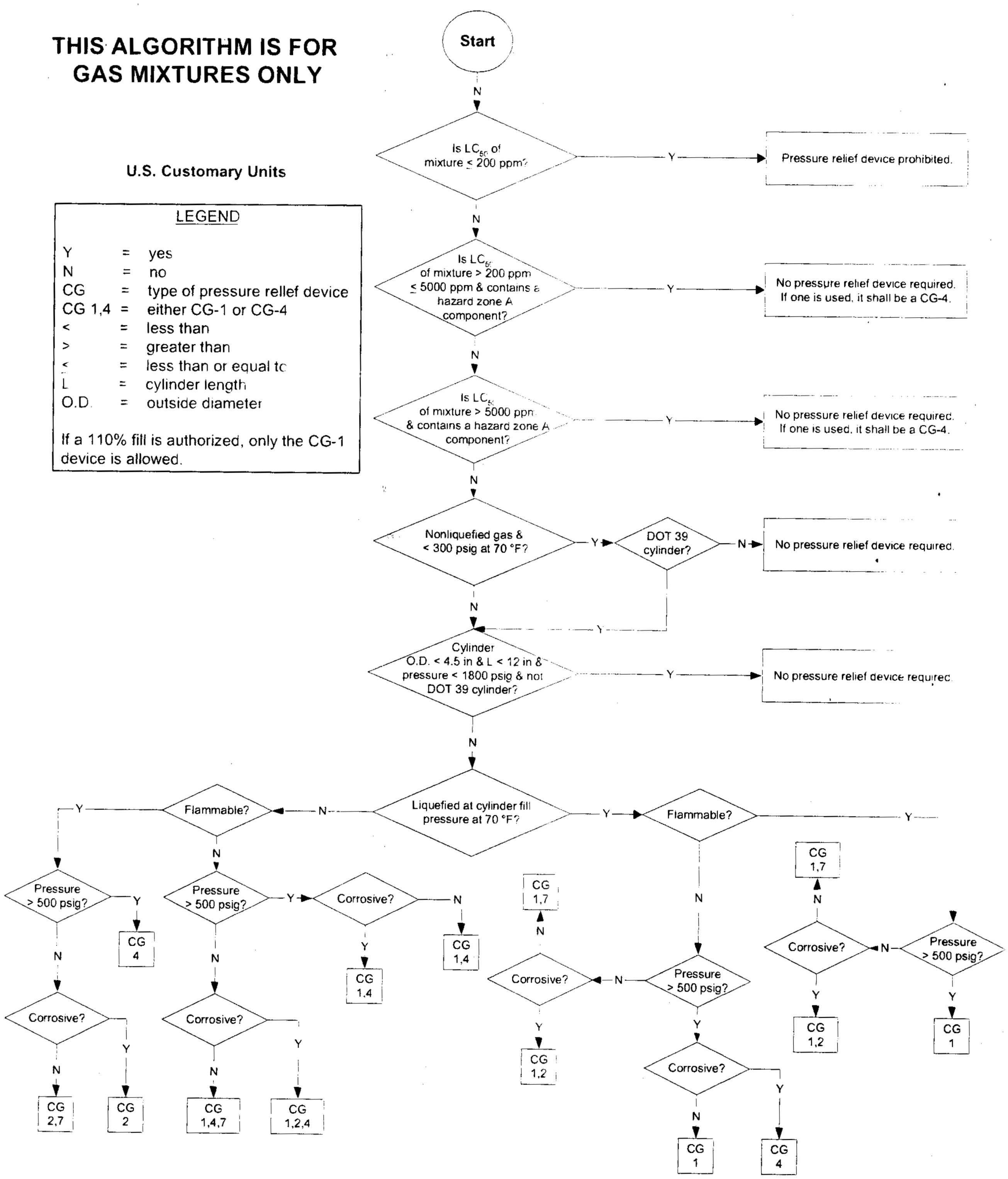


Figure 1—Algorithm for gas mixtures (U.S. customary units)

THIS ALGORITHM IS FOR GAS MIXTURES ONLY

S.I. Units

LEGEND

Y	=	yes
N	=	no
CG	=	type of pressure relief device
CG 1,4	=	either CG-1 or CG-4
$<$	=	less than
$>$	=	greater than
$\le$	=	less than or equal to
L	=	cylinder length
O.D.	=	outside diameter

If a 110% fill is authorized, only the CG-1 device is allowed.

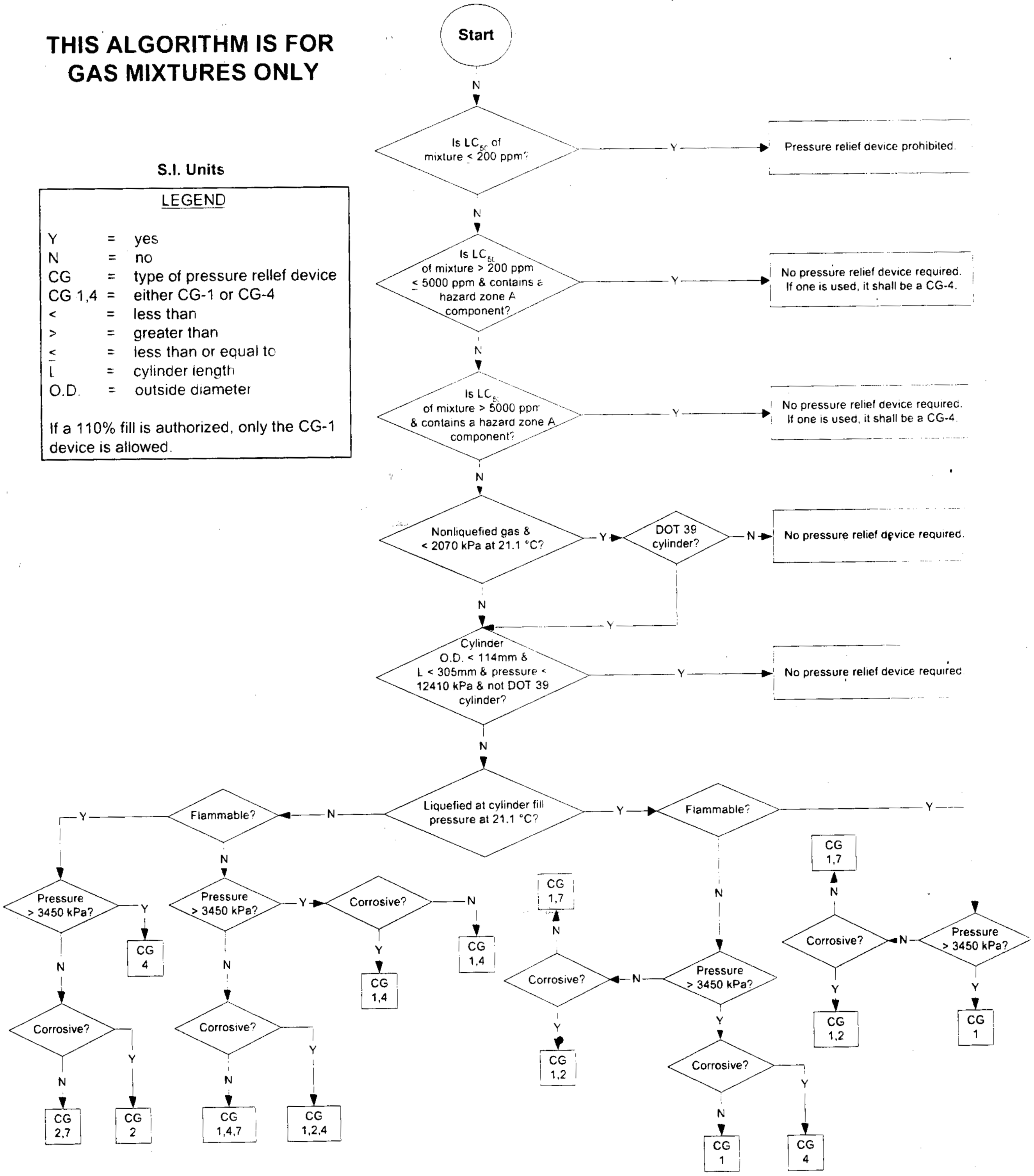


Figure 2—Algorithm for gas mixtures (SI units)

Worksheet for Example 1
100 ppm hydrogen, balance nitrogen

	COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.	Hydrogen	100 ppm	2	1	6	0	> 5000 ppm
2.	Nitrogen	Balance	0	1	6	0	> 5000 ppm

DOT CYLINDER RATING: 3AA2015

FINAL PRESSURE: 2000 psig at 70 °F
2226 psig at 130 °F

DIMENSIONS: 9 in diameter 51 in length

MIXTURE FTSC: 0 1 6 0

MIXTURE LC_{50}: > 5000 ppm

STEPS ON ALGORITHM: (See Example 1)

1. Mixture LC_{50} is > 200 ppm.
2. Mixture is nonliquefied but pressure is > 300 psig.
3. Cylinder has an O.D. > 4.5 in.
4. Mixture nonliquefied at 70 °F.
5. Mixture is nonflammable (as determined by gas producer).
6. Pressure is > 500 psig.
7. Mixture is not corrosive (as determined by gas producer).
8. Pressure relief device is CG-1 or CG-4.

OBSERVATIONS:

1. Either device is suitable.
2. Since the length of the cylinder is < 65 in, only one pressure relief device is required.
3. The pressure in the cylinder at 130 °F will be < 5/4 times the service pressure of 2015 psig.

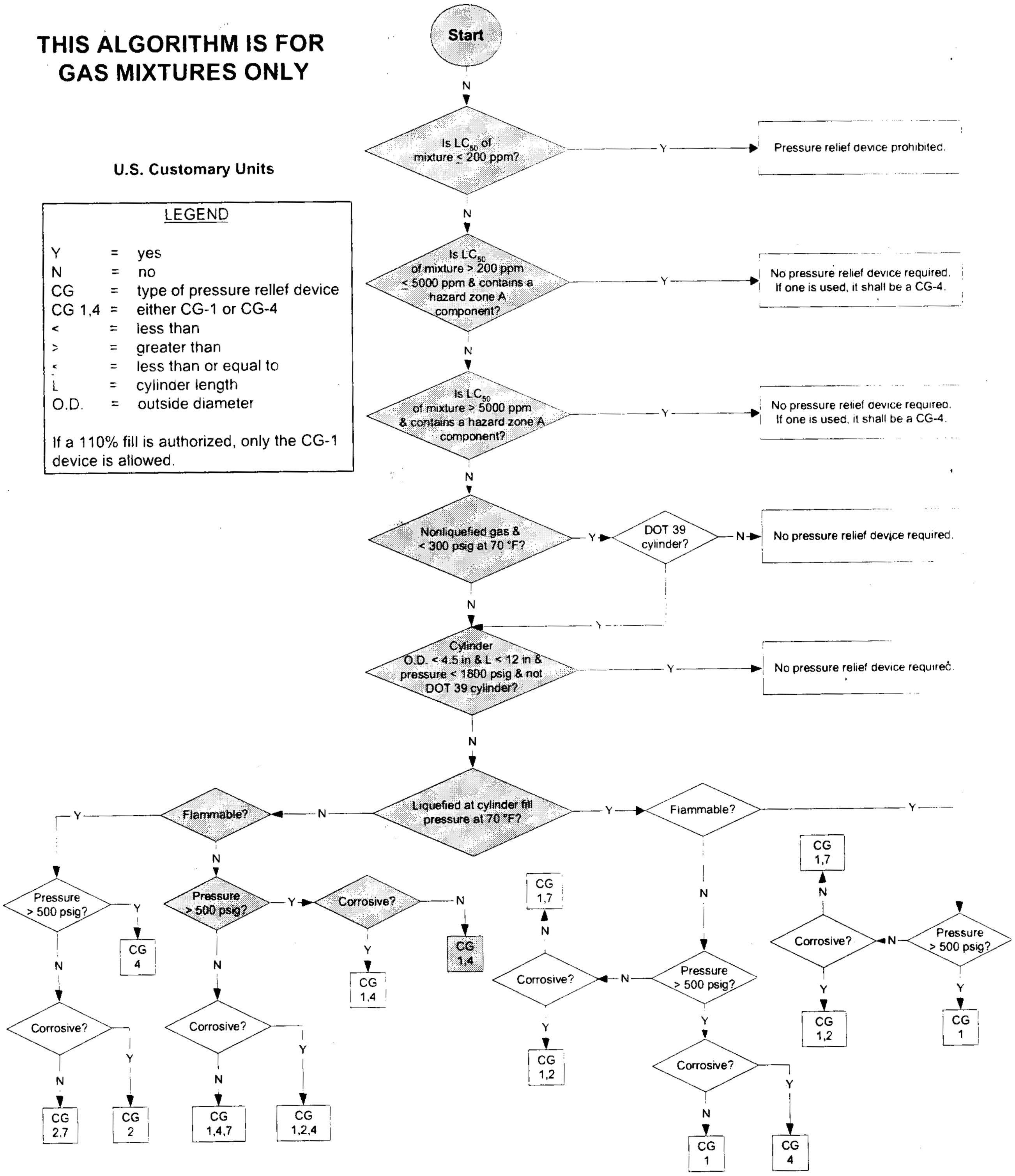
THIS ALGORITHM IS FOR GAS MIXTURES ONLY

U.S. Customary Units

LEGEND

Y	=	yes
N	=	no
CG	=	type of pressure relief device
CG 1,4	=	either CG-1 or CG-4
<	=	less than
>	=	greater than
≤	=	less than or equal to
L	=	cylinder length
O.D.	=	outside diameter

If a 110% fill is authorized, only the CG-1 device is allowed.



Example 1—100 ppm hydrogen, balance nitrogen

Worksheet for Example 2
5% trimethylamine, balance sulfur hexafluoride
(U.S. customary units)

	COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.	Trimethylamine	5%	2	1	0	2	7000 ppm
2.	Sulfur hexafluoride	Balance	0	1	0	0	> 5000 ppm

DOT CYLINDER RATING: 3AA2015

FINAL PRESSURE: 250 psig at 70 °F
278 psig at 130 °F

DIMENSIONS: 9 in diameter 51 in length

$$LC_{50,mix} = \frac{LC_{50,trimethylamine}}{Concentration_{trimethylamine}} = \frac{7000}{0.05} = 140\,000 \text{ ppm}$$

MIXTURE FTSC: 2 1 0 2

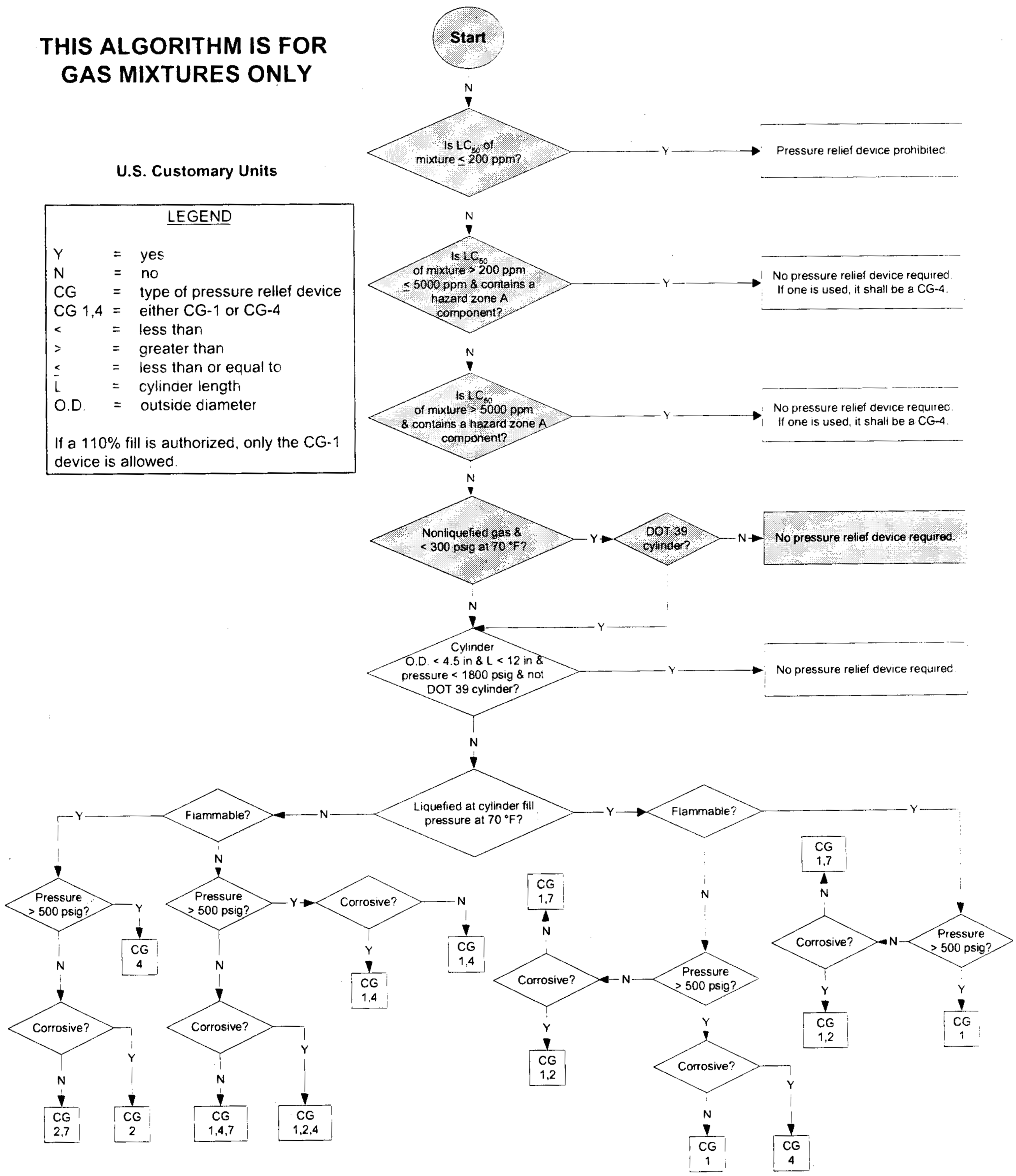
MIXTURE LC_{50}: 140 000 ppm

STEPS ON ALGORITHM: (See Example 2)

1. Mixture LC_{50} is > 200 ppm.
2. Mixture is nonliquefied and pressure is < 300 psig.
3. Cylinder is not DOT 39.
4. No pressure relief device is required.

OBSERVATIONS:

No pressure relief device is required.



Example 2—5% trimethylamine, balance sulfur hexafluoride (U.S. customary units)

Worksheet for Example 3
5% trimethylamine, balance sulfur hexafluoride
(SI units)

	COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.	Trimethylamine	5%	2	1	0	2	7000 ppm
2.	Sulfur hexafluoride	Balance	0	1	0	0	> 5000 ppm

DOT CYLINDER RATING: 3AA2015

FINAL PRESSURE: 1720 kPa at 21.1 °C
1916 kPa at 54.4 °C

DIMENSIONS: 229 mm diameter 1295 mm length

$$LC_{50,mix} = \frac{LC_{50,trimethylamine}}{Concentration_{trimethylamine}} = \frac{7000}{0.05} = 140\,000 \text{ ppm}$$

MIXTURE FTSC: 2 1 0 2

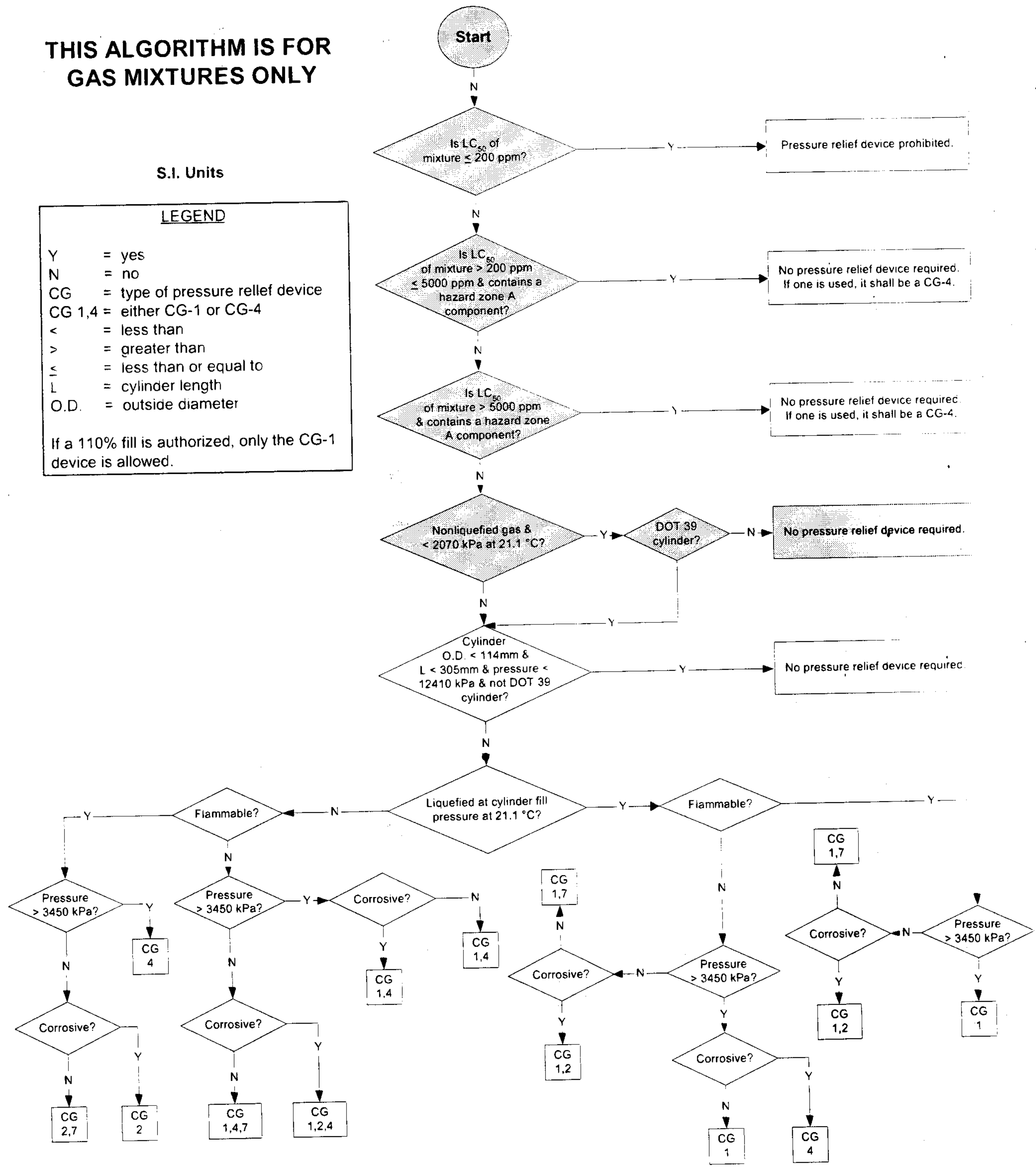
MIXTURE LC_{50}: 140 000 ppm

STEPS ON ALGORITHM: (See Example 3)

1. Mixture LC_{50} is > 200 ppm.
2. Mixture is nonliquefied and pressure is < 2070 kPa.
3. Cylinder is not DOT 39.
4. No pressure relief device is required.

OBSERVATIONS:

No pressure relief device is required.



Example 3—5% trimethylamine, balance sulfur hexafluoride (SI units)

Worksheet for Example 4
0.5% oxygen, 0.5% nitrogen, balance methane

	COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.	Oxygen	0.5%	4	0	6	0	> 5000 ppm
2.	Nitrogen	0.5%	0	1	6	0	> 5000 ppm
3.	Methane	Balance	2	1	6	0	> 5000 ppm

DOT CYLINDER RATING: 3AX2400

FINAL PRESSURE: 2400 psig at 70 °F
2671 psig at 130 °F

DIMENSIONS: 9.5 in diameter 252 in length

All mixture components have LC_{50} values above 5000 ppm, but oxygen is < 19.5%, therefore the T code is 1.

MIXTURE FTSC: 2 1 6 0

MIXTURE LC_{50}: >5000 ppm

STEPS ON ALGORITHM: (See Example 4)

1. Mixture LC_{50} is > 200 ppm.
2. Mixture is nonliquefied but pressure > 300 psig.
3. Cylinder has an O.D. > 4.5 in.
4. Mixture is nonliquefied at 70 °F.
5. Mixture is flammable (as determined by gas producer).
6. Pressure > 500 psig.
7. Pressure relief device is CG-4.

OBSERVATIONS:

1. Since the length of the cylinder is > 65 in, a pressure relief device is required at each end.
2. The pressure in the cylinder at 130 °F is <5/4 times the service pressure of 2400 psig.
3. Since the mixture has been deemed to be predominantly methane, then CGA S-1.1 permits a CG-1, CG-4, or CG-5 [4]. The CG-7 may not be used since the final fill pressure is > 500 psig.

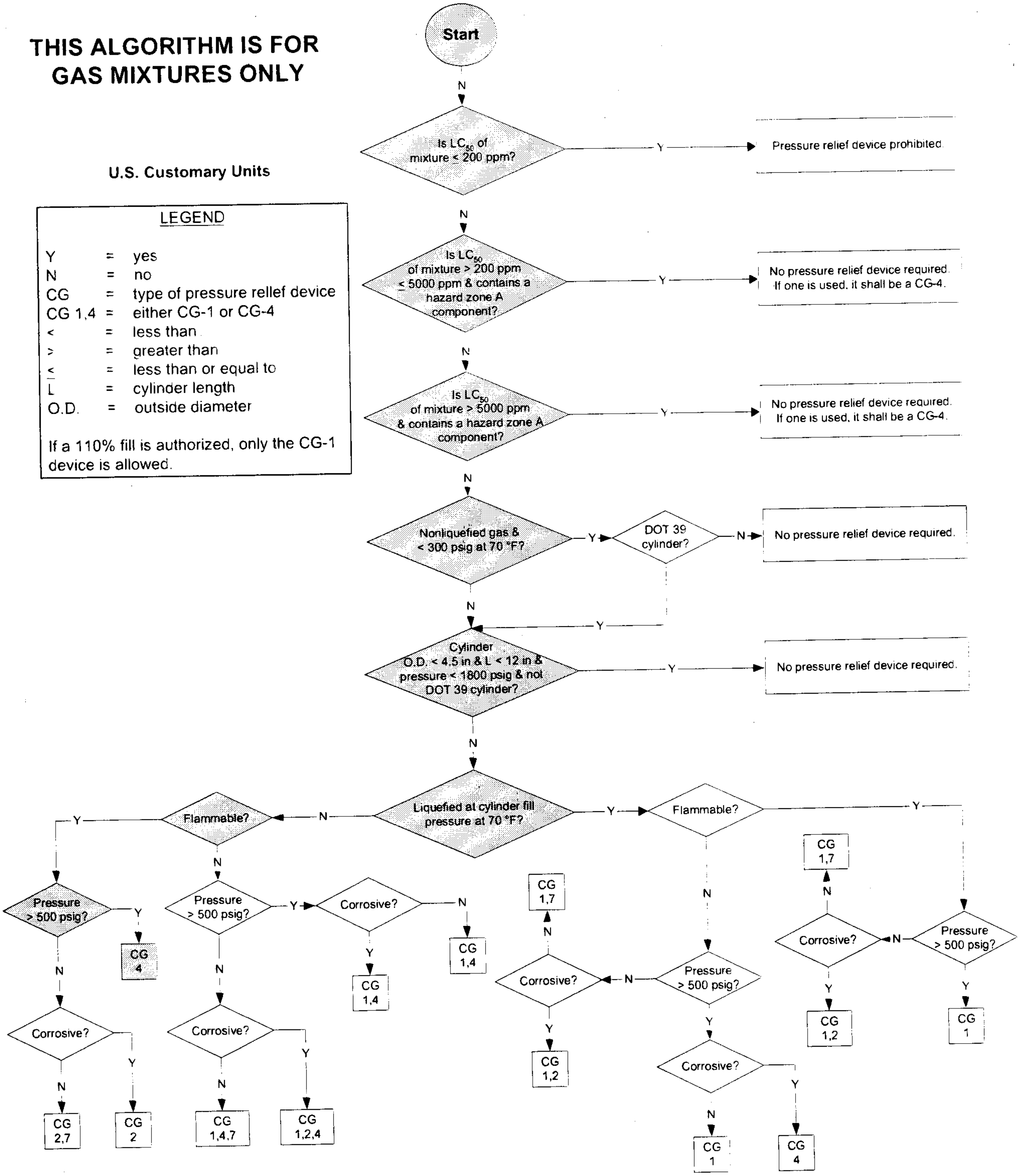
THIS ALGORITHM IS FOR GAS MIXTURES ONLY

U.S. Customary Units

LEGEND

Y	=	yes
N	=	no
CG	=	type of pressure relief device
CG 1,4	=	either CG-1 or CG-4
<	=	less than
>	=	greater than
≤	=	less than or equal to
L	=	cylinder length
O.D.	=	outside diameter

If a 110% fill is authorized, only the CG-1 device is allowed.



Example 4—0.5% oxygen, 0.5% nitrogen, balance methane

Worksheet for Example 5
12% ethylene oxide, balance dichlorodifluoromethane (R12)

	COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.	Ethylene oxide	12%	5	2	0	0	2920 ppm
2.	Refrigerant-12	Balance	0	1	0	0	> 5000 ppm

DOT CYLINDER RATING: 4BA240

FINAL PRESSURE 70 psig at 70 °F
78 psig at 130 °F

DIMENSIONS: 10.5 in diameter 55 in length

$$LC_{50,mix} = \frac{LC_{50,\text{ethylene oxide}}}{\text{Concentration}_{\text{ethylene oxide}}} = \frac{2920}{0.12} = 24\,333 \text{ ppm}$$

MIXTURE FTSC: 0 1 2 0

MIXTURE LC_{50}: > 5000 ppm

STEPS ON ALGORITHM: (See Example 5)

1. Mixture LC_{50} is > 200 ppm.
2. Mixture is liquefied but pressure is < 300 psig.
3. Cylinder has an O.D. > 4.5 in.
4. Mixture is liquefied at 70 °F.
5. Mixture is nonflammable (as determined by gas producer).
6. Pressure is < 500 psig.
7. Mixture is not corrosive (as determined by gas producer).
8. Pressure relief device is either CG-1 or CG-7.

OBSERVATIONS:

1. Either device is suitable.
2. Since the length of the cylinder is < 65 in, only one pressure relief device is required.
3. The pressure in the cylinder at 130 °F is < 5/4 times the service pressure of 240 psig.

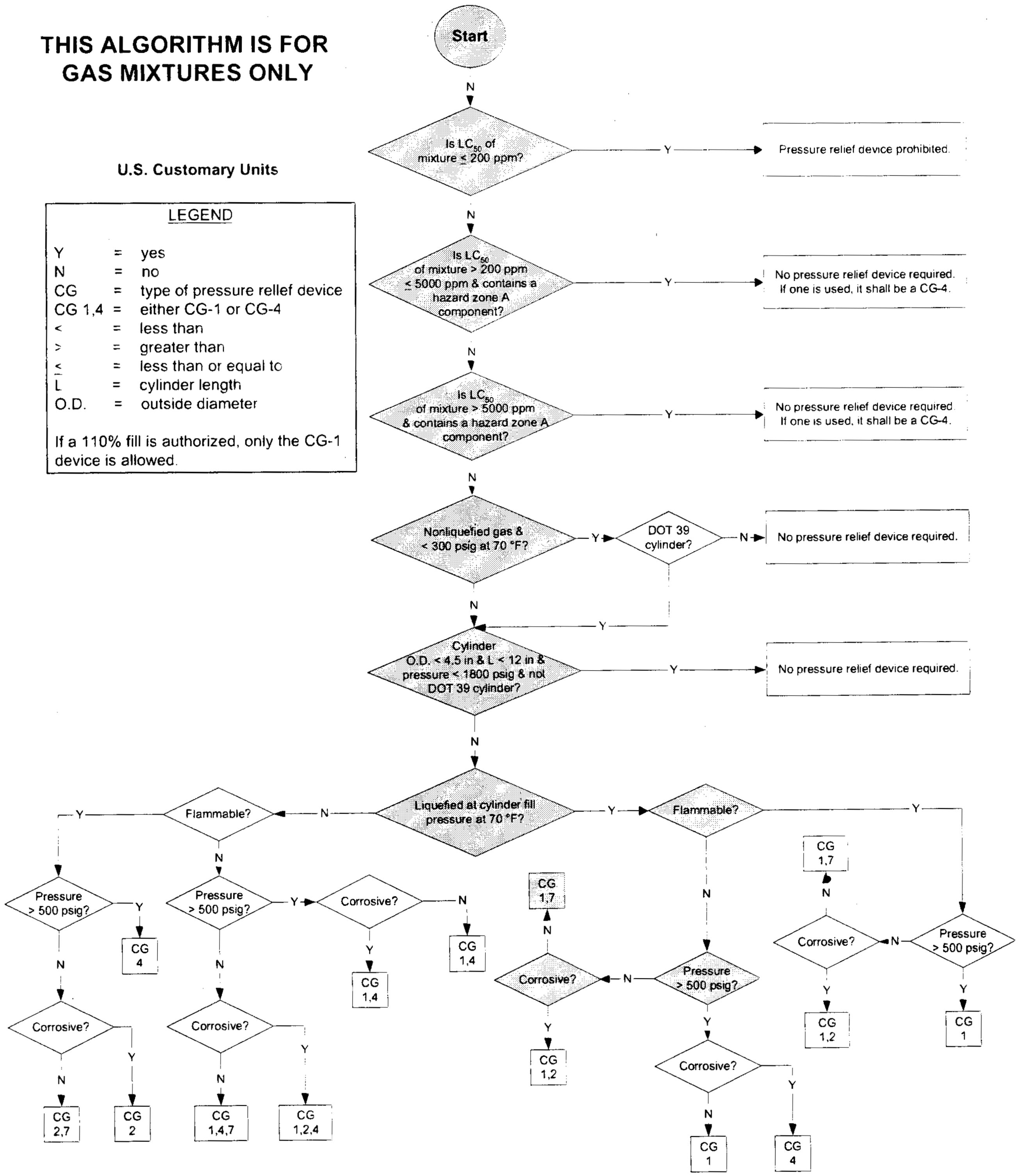
THIS ALGORITHM IS FOR GAS MIXTURES ONLY

U.S. Customary Units

LEGEND

Y	=	yes
N	=	no
CG	=	type of pressure relief device
CG 1,4	=	either CG-1 or CG-4
<	=	less than
>	=	greater than
≤	=	less than or equal to
L	=	cylinder length
O.D.	=	outside diameter

If a 110% fill is authorized, only the CG-1 device is allowed.



Example 5—12% ethylene oxide, balance dichlorodifluoromethane (R12)

Worksheet for Example 6
5% carbon dioxide, balance oxygen
(DOT 3AA2015 cylinder)

	COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.	Carbon Dioxide	5%	0	1	6	0	> 5000 ppm
2.	Oxygen	Balance	4	0	6	0	> 5000 ppm

DOT CYLINDER RATING: 3AA2015

FINAL PRESSURE: 2000 psig at 70 °F
2226 psig at 130 °F

DIMENSIONS: 9 in diameter 51 in length

ALL mixture components have LC_{50} values above 5000 ppm, and oxygen is > 19.5%, therefore the T code is 0.

MIXTURE FTSC: 4 0 6 0

MIXTURE LC_{50}: > 5000 ppm

STEPS ON ALGORITHM: (See Example 6)

1. Mixture LC_{50} is > 200 ppm.
2. Mixture is nonliquefied but pressure > 300 psig.
3. Cylinder has an O.D. > 4.5 in.
4. Mixture is nonliquefied at 70 °F.
5. Mixture is nonflammable (as determined by gas producer).
6. Pressure is > 500 psig.
7. Mixture is not corrosive (as determined by gas producer).
8. Pressure relief device is CG-1 or CG-4.

OBSERVATIONS:

1. Either device is suitable.
2. As the length of the cylinder is < 65 in, only one pressure relief device is required.
3. The pressure in the cylinder at 130 °F is <5/4 times the service pressure of 2015 psig.

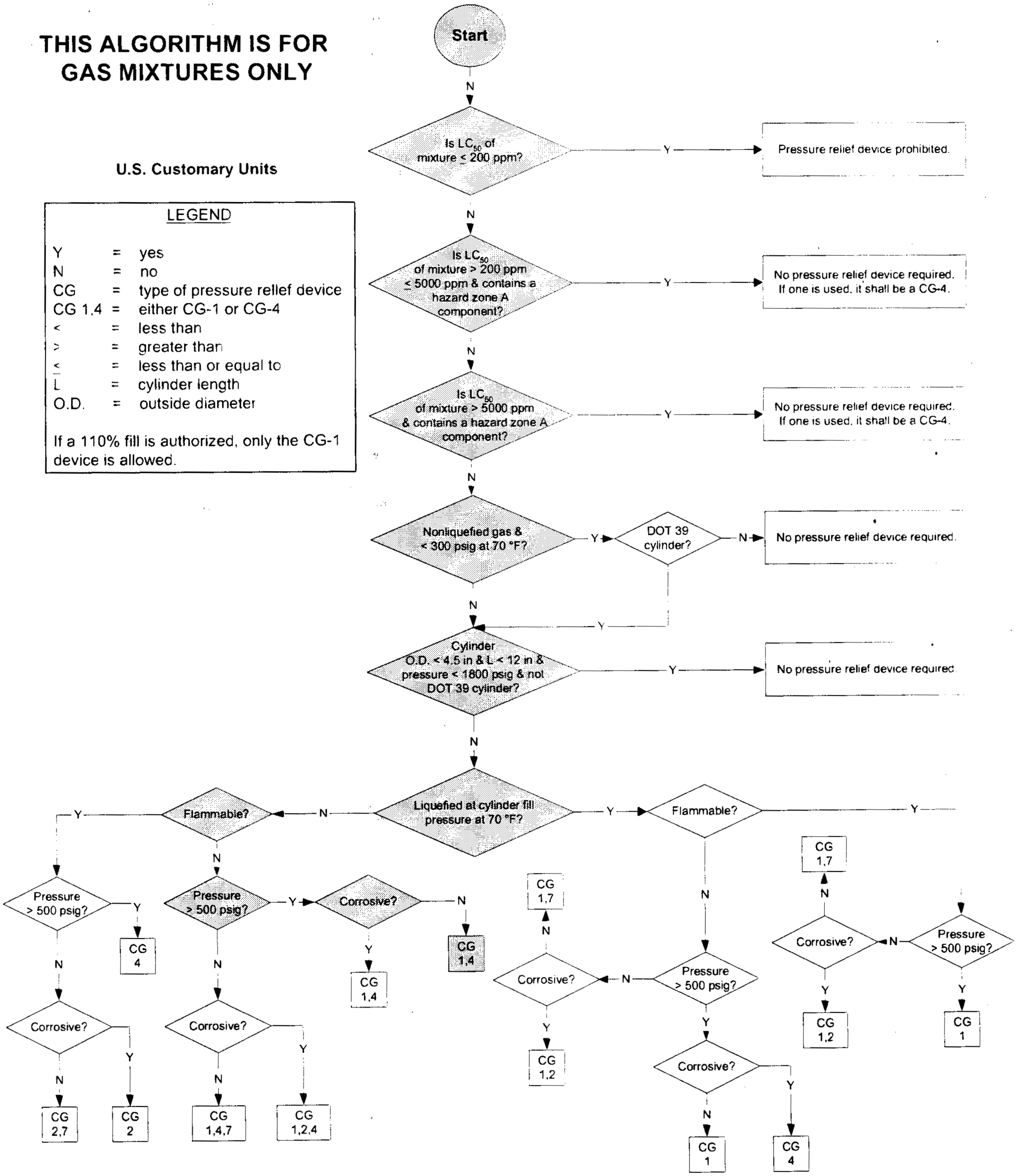
THIS ALGORITHM IS FOR GAS MIXTURES ONLY

U.S. Customary Units

LEGEND

Y	=	yes
N	=	no
CG	=	type of pressure relief device
CG 1,4	=	either CG-1 or CG-4
<	=	less than
>	=	greater than
≤	=	less than or equal to
L	=	cylinder length
O.D.	=	outside diameter

If a 110% fill is authorized, only the CG-1 device is allowed.



Example 6—5% carbon dioxide, balance oxygen (DOT 3AA2015 cylinder)

Worksheet for Example 7
5% carbon dioxide, balance oxygen
(DOT 3E1800 cylinder)

	COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.	Carbon dioxide	5%	0	1	6	0	> 5000 ppm
2.	Oxygen	Balance	4	0	6	0	> 5000 ppm

DOT CYLINDER RATING: 3EI800

FINAL PRESSURE: 1750 psig at 70 °F
1948 psig at 130 °F

DIMENSIONS: 2 in diameter 12 in length

All mixture components have LC_{50} values above 5000 ppm and oxygen is > 19.5%, therefore the T code is 0.

MIXTURE FTSC: 4 0 6 0

MIXTURE LC_{50}: > 5000 ppm

STEPS ON ALGORITHM: (See Example 7)

1. Mixture LC_{50} is > 200 ppm.
2. Mixture is nonliquefied but pressure > 300 psig.
3. Cylinder O.D. < 4.5 in, length < 12 in, final pressure < 1800 psig and not DOT 39.
4. No pressure relief device is required.

OBSERVATIONS:

The pressure in the cylinder at 130 °F is < 5/4 times the service pressure of 1800 psig.

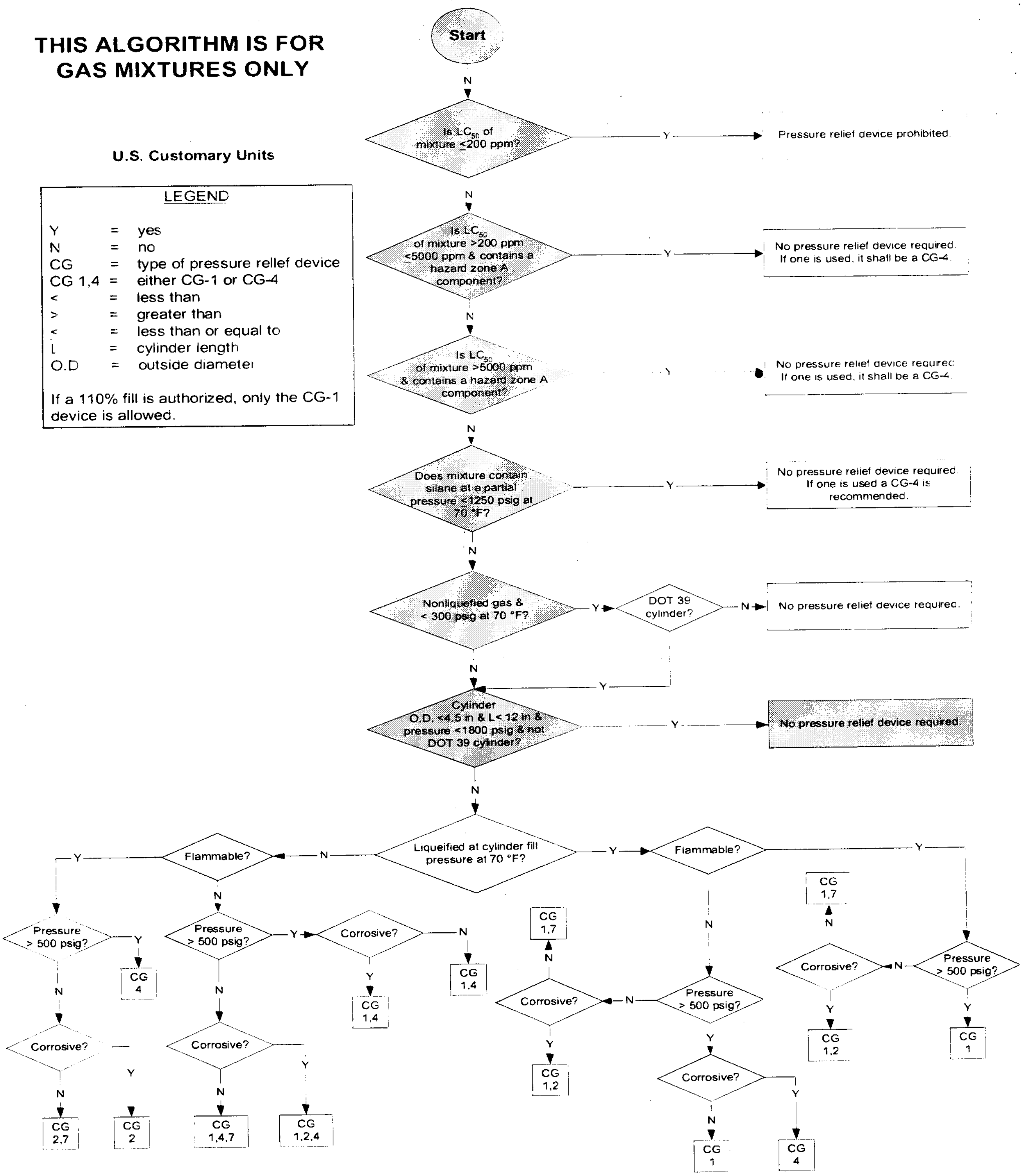
THIS ALGORITHM IS FOR GAS MIXTURES ONLY

U.S. Customary Units

LEGEND

Y	=	yes
N	=	no
CG	=	type of pressure relief device
CG 1,4	=	either CG-1 or CG-4
<	=	less than
>	=	greater than
≤	=	less than or equal to
L	=	cylinder length
O.D	=	outside diameter

If a 110% fill is authorized, only the CG-1 device is allowed.



Example 7—5% carbon dioxide, balance oxygen (DOT 3E1800 cylinder)

Worksheet for Example 8
Multicomponent gas mixtures

	COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.	Methane	4%	2	1	6	0	> 5000 ppm
2.	Propane	4%	2	1	0	0	> 5000 ppm
3.	Ethane	4%	2	1	1	0	> 5000 ppm
4.	Carbon Monoxide	4%	2	2	6	0	3760 ppm
5.	Hydrogen	4%	2	1	6	0	> 5000 ppm
6.	Oxygen	5.5%	4	0	6	0	> 5000 ppm
7.	Nitrogen	Balance	0	1	6	0	> 5000 ppm

DOT CYLINDER RATING: 3AA2015

FINAL PRESSURE: 1650 psig at 70 °F
1837 psig at 130 °F

DIMENSIONS: 9 in diameter 51 in length

$$LC_{50,mix} = \frac{LC_{50,\text{carbon monoxide}}}{\text{Concentration}_{\text{carbon monoxide}}} = \frac{3760}{0.04} = 94\,000 \text{ ppm}$$

MIXTURE FTSC: 2 1 6 0

MIXTURE LC_{50}: 94 000 ppm

STEPS ON ALGORITHM: (See Example 8)

1. Mixture LC_{50} is > 200 ppm.
2. Mixture is nonliquefied, pressure > 300 psig.
3. Cylinder has an O.D. > 4.5 in.
4. Mixture is nonliquefied at 70 °F.
5. Mixture is flammable (as determined by gas producer).
6. Pressure is > 500 psig.
7. Pressure relief device is CG-4.

OBSERVATIONS:

1. Since the length of the cylinder is < 65 in, only one pressure relief device is required.
2. The pressure in the cylinder at 130 °F is <5/4 times the service pressure of 2015 psig.

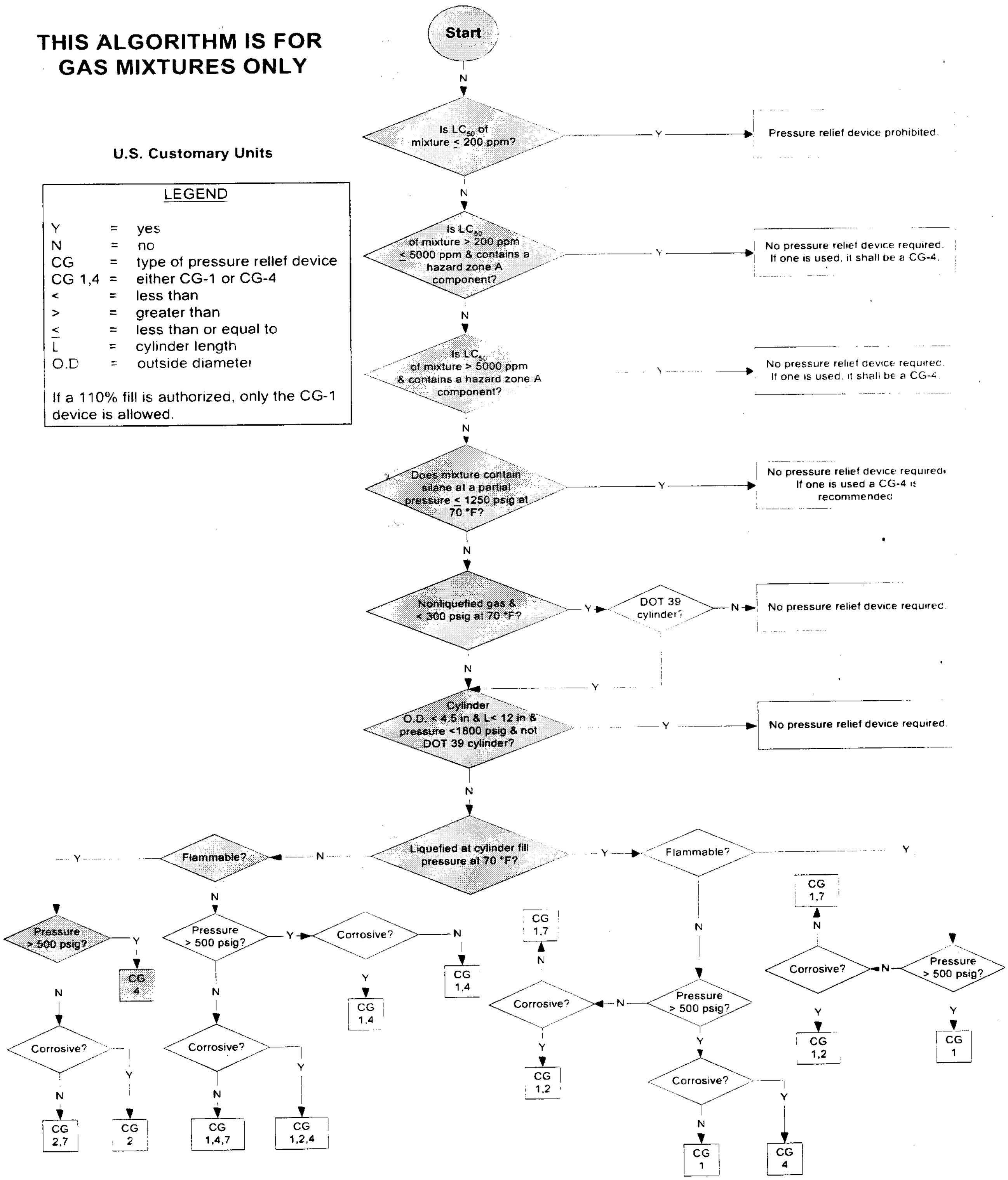
THIS ALGORITHM IS FOR GAS MIXTURES ONLY

U.S. Customary Units

LEGEND

Y	=	yes
N	=	no
CG	=	type of pressure relief device
CG 1,4	=	either CG-1 or CG-4
<	=	less than
>	=	greater than
≤	=	less than or equal to
L	=	cylinder length
O.D	=	outside diameter

If a 110% fill is authorized, only the CG-1 device is allowed.



Example 8—Multicomponent gas mixtures

Worksheet for Example 9
20% arsine, balance hydrogen

	COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.	Arsine	20%	2	3	0	0	20 ppm
2.	Hydrogen	Balance	2	1	6	0	> 5000 ppm

DOT CYLINDER RATING: 3AA2015

FINAL PRESSURE: 600 psig at 70 °F
669 psig at 130 °F

DIMENSIONS: 9 in diameter 15 in length

Both components are flammable, so the mixture F code is 2 (as determined by the mixture producer).

$$LC_{50,mix} = \frac{LC_{50,arsine}}{Concentration_{arsine}} = \frac{20}{0.20} = 100 \text{ ppm}$$

The mixture is a nonliquefied gas between 600 psig and 3000 psig, so the mixture S code is 6 (as determined by the mixture producer).

Neither component is corrosive, so the mixture C code is 0 (as determined by the mixture producer).

MIXTURE FTSC: 2 3 6 0

MIXTURE LC_{50}: 100 ppm

STEPS ON ALGORITHM: (See Example 9)

1. Mixture LC_{50} is ≤ 200 ppm.
2. Pressure relief device is prohibited.

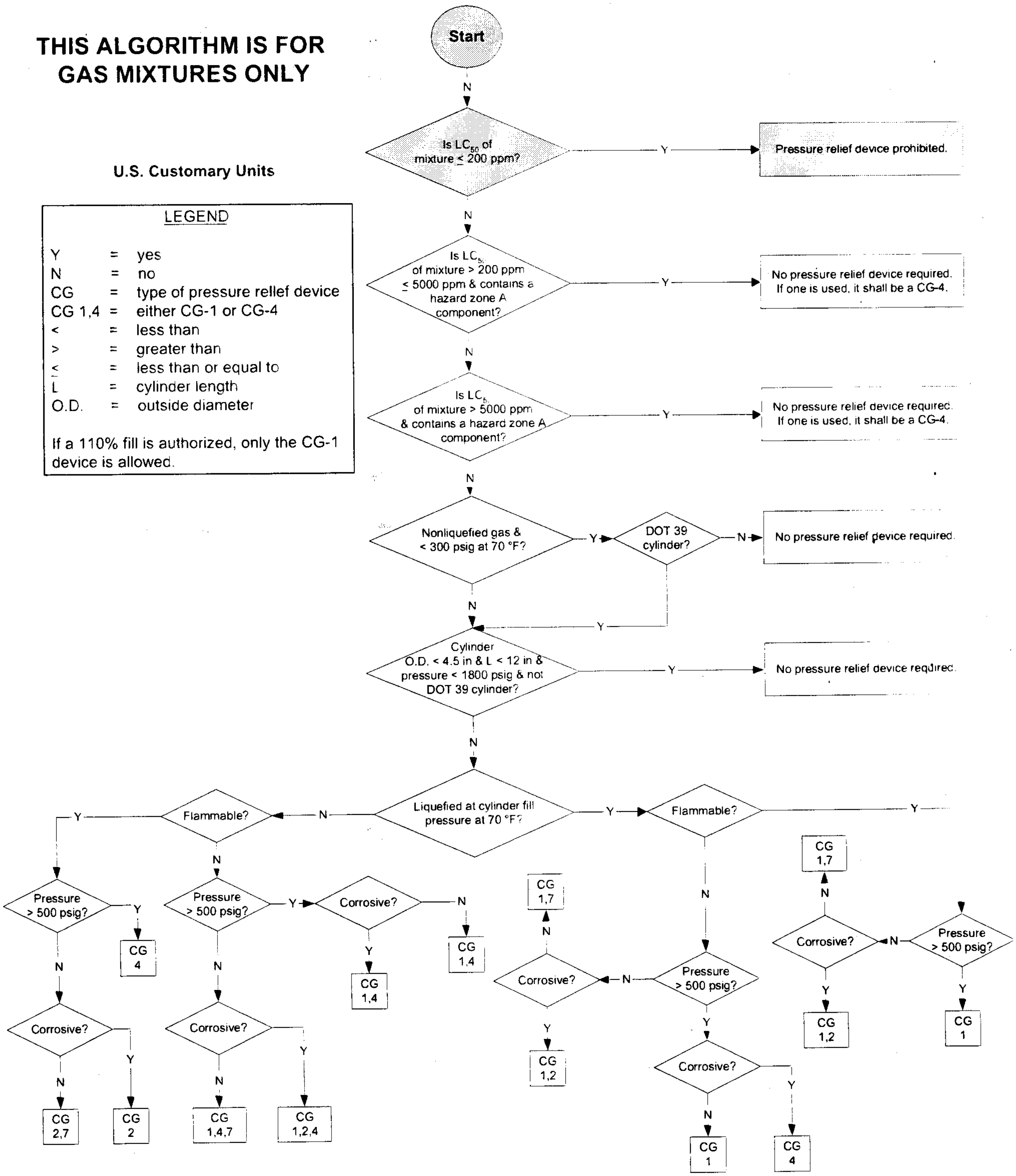
THIS ALGORITHM IS FOR GAS MIXTURES ONLY

U.S. Customary Units

LEGEND

Y	=	yes
N	=	no
CG	=	type of pressure relief device
CG 1,4	=	either CG-1 or CG-4
<	=	less than
>	=	greater than
≤	=	less than or equal to
L	=	cylinder length
O.D.	=	outside diameter

If a 110% fill is authorized, only the CG-1 device is allowed.



Example 9—20% arsine, balance hydrogen

Worksheet for Example 10
2% arsine, balance hydrogen

	COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.	Arsine	2%	2	3	0	0	20 ppm
2.	Hydrogen	Balance	2	1	6	0	> 5000 ppm

DOT CYLINDER RATING: 3AA2015

FINAL PRESSURE: 1000 psig at 70 °F
1113 psig at 130 °F

DIMENSIONS: 9 in diameter 15 in length

Both components are flammable, so the mixture F code is 2 (as determined by the mixture producer).

$$LC_{50,mix} = \frac{LC_{50,arsine}}{\text{Concentration}_{arsine}} = \frac{20}{0.02} = 1000 \text{ ppm}$$

The mixture is a nonliquefied gas between 500 psig and 3000 psig, so the S code is 6 (as determined by the mixture producer).

Neither component is corrosive, so the mixture C code is 0 (as determined by the mixture producer).

MIXTURE FTSC: 2 2 6 0

MIXTURE LC_{50}: 1000 ppm

STEPS ON ALGORITHM: (See Example 10)

1. Mixture LC_{50} is > 200 ppm.
2. Mixture LC_{50} is > 200 ppm, ≤ 5000 ppm, and the mixture contains a Hazard Zone A component.
3. No pressure relief device is required. If one is used, it shall be CG-4.

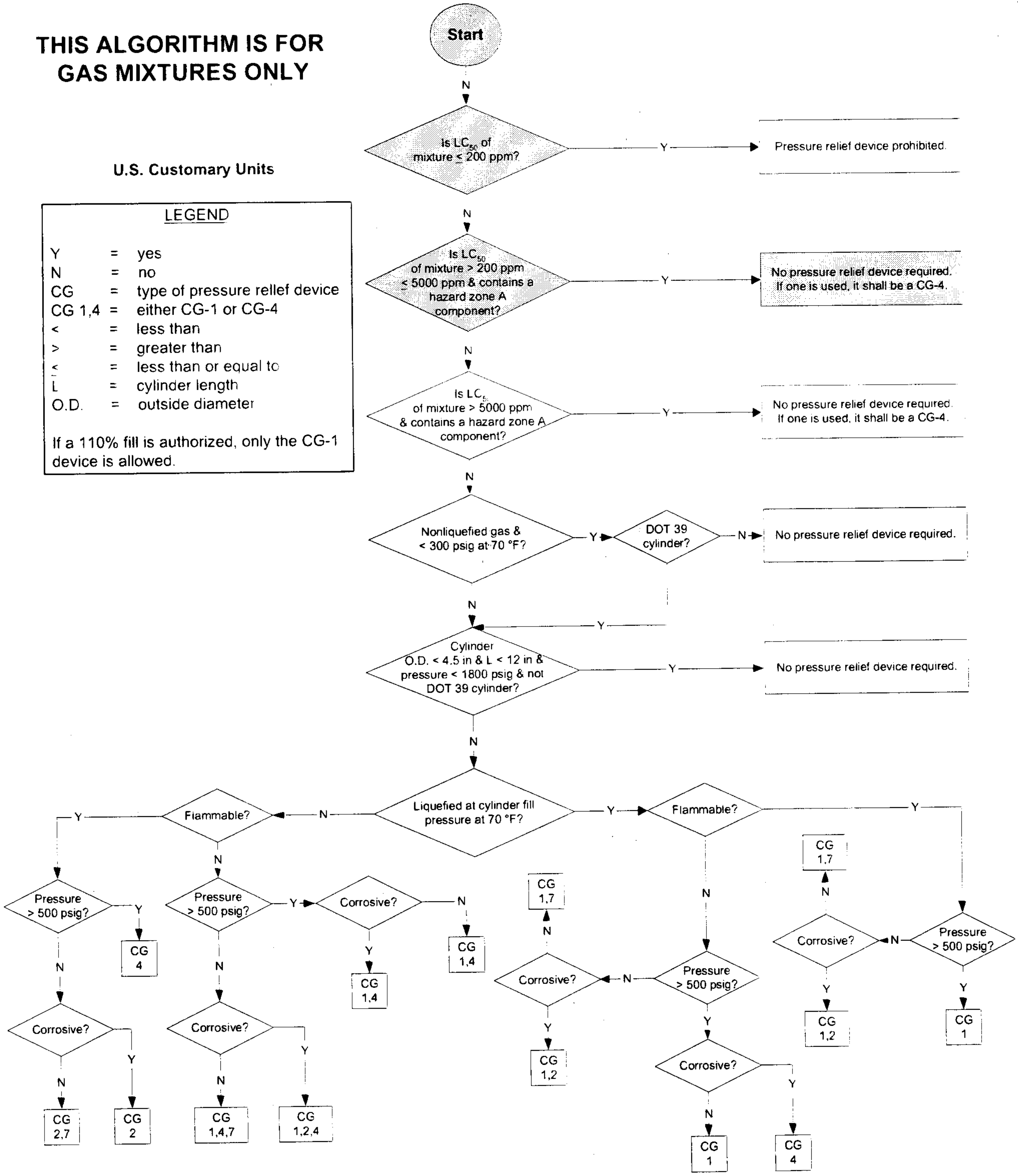
THIS ALGORITHM IS FOR GAS MIXTURES ONLY

U.S. Customary Units

LEGEND

Y = yes
N = no
CG = type of pressure relief device
CG 1,4 = either CG-1 or CG-4
< = less than
> = greater than
≤ = less than or equal to
L = cylinder length
O.D. = outside diameter

If a 110% fill is authorized, only the CG-1 device is allowed.



Example 10—2% arsine, balance hydrogen

Worksheet for Example 11
0.2% arsine, balance hydrogen

	COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.	Arsine	0.2%	2	3	0	0	20 ppm
2.	Hydrogen	Balance	2	1	6	0	> 5000 ppm

DOT CYLINDER RATING: 3AA2015

FINAL PRESSURE: 1000 psig at 70 °F
1113 psig at 130 °F

DIMENSIONS: 9 in diameter 15 in length

Both components are flammable, so the mixture F code is 2 (as determined by the mixture producer).

$$LC_{50,mix} = \frac{LC_{50,\,arsine}}{Concentration_{arsine}} = \frac{20}{0.002} \doteq 10\,000 \text{ ppm}$$

The mixture is a nonliquefied gas between 500 psig and 3000 psig, so the mixture S code is 6 (as determined by the mixture producer).

Neither component is corrosive, so the mixture C code is 0 (as determined by the mixture producer).

MIXTURE FTSC: 2 1 6 0

MIXTURE LC_{50}: 10 000 ppm

STEPS ON ALGORITHM: (See Example 11)

1. Mixture LC_{50} > 200 ppm.
2. Mixture LC_{50} is > 5000 ppm, and the mixture contains a Hazard Zone A component.
3. No pressure relief device is required. If one is used, it shall be a CG-4.

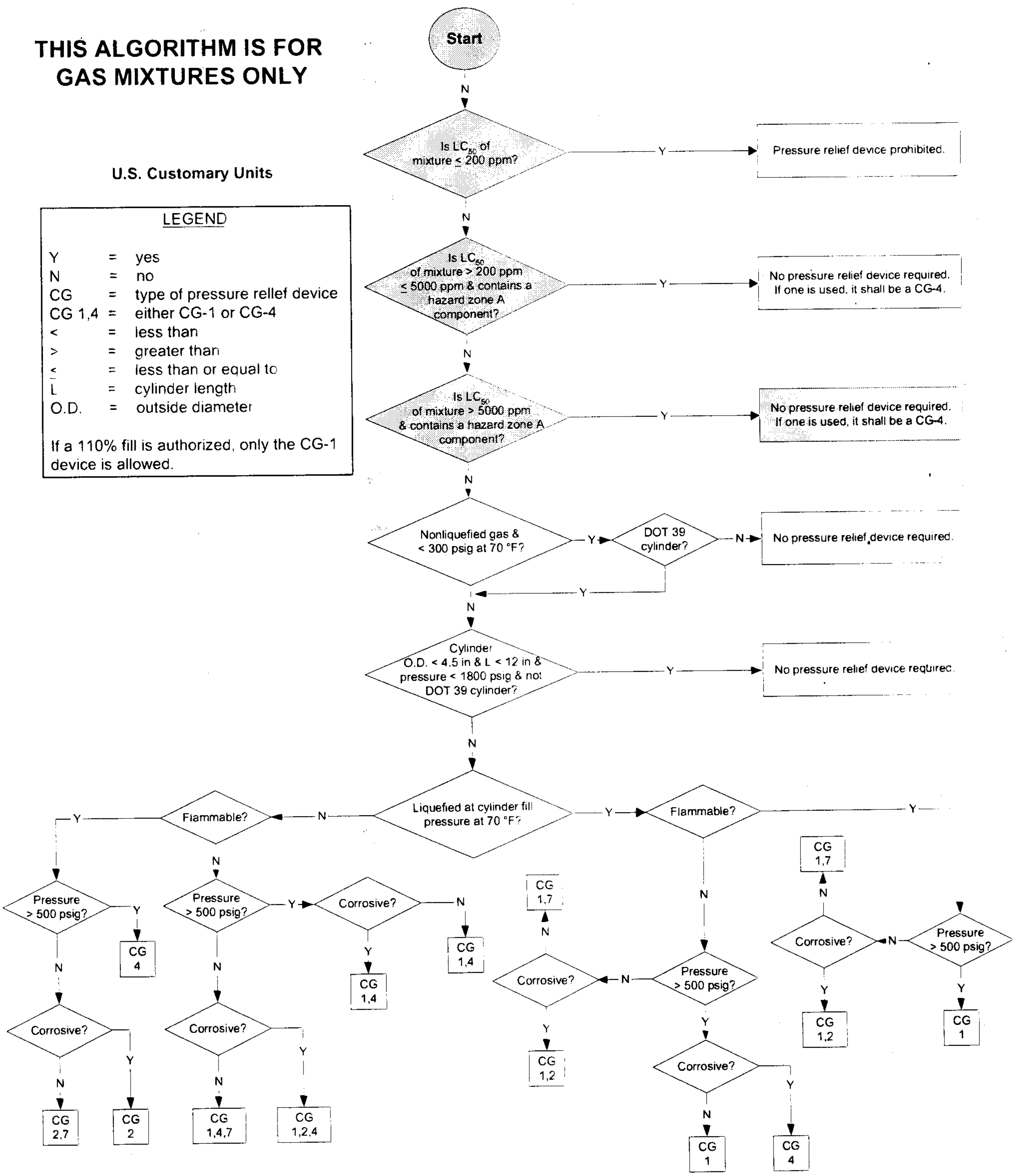
THIS ALGORITHM IS FOR GAS MIXTURES ONLY

U.S. Customary Units

LEGEND

Y	=	yes
N	=	no
CG	=	type of pressure relief device
CG 1,4	=	either CG-1 or CG-4
<	=	less than
>	=	greater than
≤	=	less than or equal to
L	=	cylinder length
O.D.	=	outside diameter

If a 110% fill is authorized, only the CG-1 device is allowed.



Example 11—0.2% arsine, balance hydrogen

Worksheet for Example 12
5% arsine, 10% phosphine, balance hydrogen

	COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.	Arsine	5%	2	3	0	0	20 ppm
2.	Phosphine	10%	3	3	1	0	20 ppm
3.	Hydrogen	Balance	2	1	6	0	> 5000 ppm

DOT CYLINDER RATING: 3AA2015

FINAL PRESSURE: 1000 psig at 70 °F
1113 psig at 130 °F

DIMENSIONS: 9 in diameter 15 in length

The mixture contains three flammable components, one of which is pyrophoric, so the mixture F code is 3 (as determined by the mixture producer).

$$LC_{50,mix} = \frac{1}{\frac{Concentration_{arsine}}{LC_{50,arsine}} + \frac{Concentration_{phosphine}}{LC_{50,phosphine}}} = \frac{1}{\frac{0.05}{20} + \frac{0.10}{20}} = 133\text{ ppm}$$

The mixture is a nonliquefied gas between 500 psig and 3000 psig, so the mixture S code is 6 (as determined by the mixture producer).

Neither component is corrosive, so the mixture C code is 0 (as determined by the mixture producer).

MIXTURE FTSC: 3 3 6 0

MIXTURE LC_{50}: 133 ppm

STEPS ON ALGORITHM: (See Example 12)

1. Mixture LC_{50} is < 200 ppm.
2. Pressure relief device is prohibited.

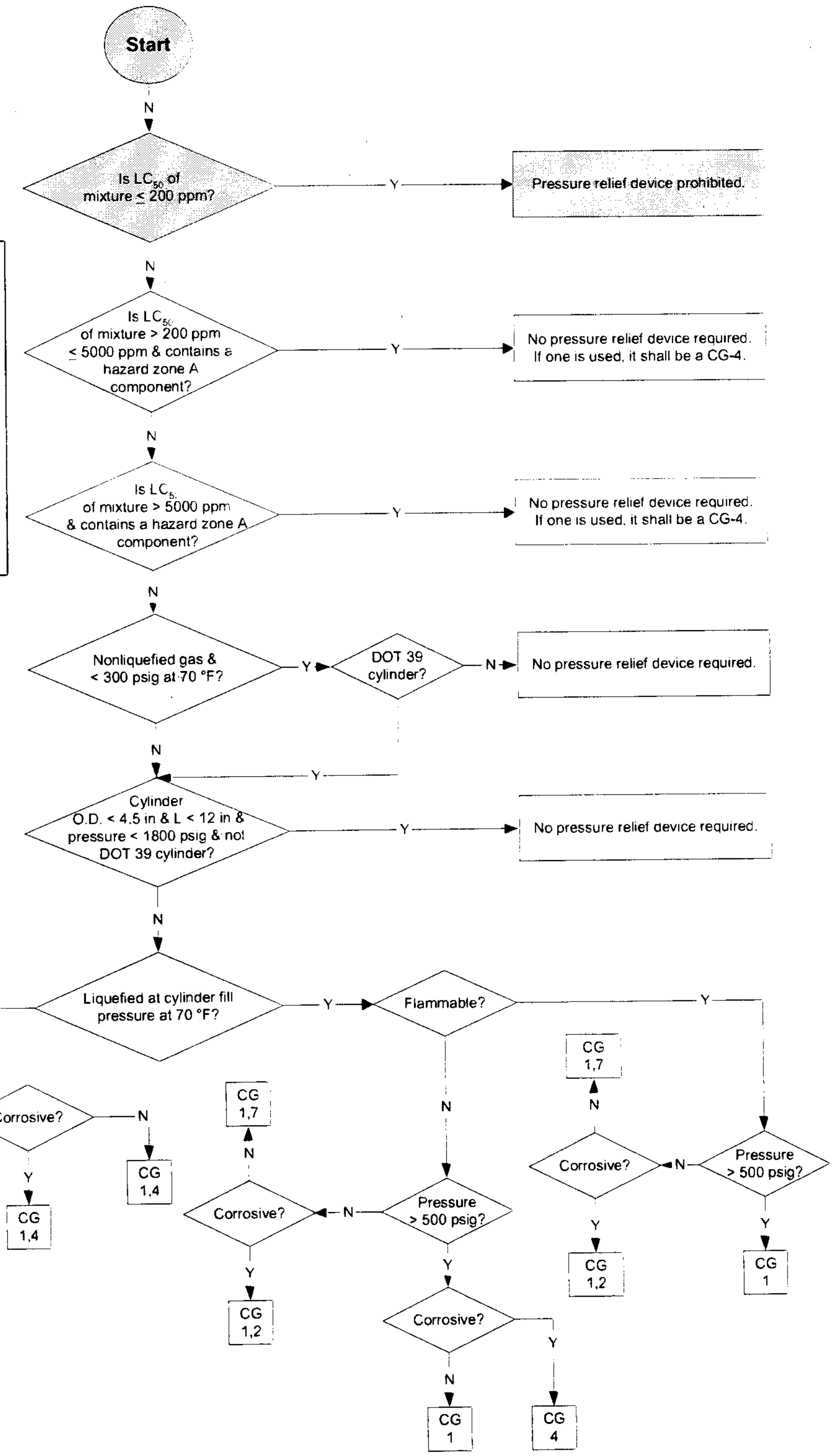
THIS ALGORITHM IS FOR GAS MIXTURES ONLY

U.S. Customary Units

LEGEND

Y	=	yes
N	=	no
CG	=	type of pressure relief device
CG 1,4	=	either CG-1 or CG-4
<	=	less than
>	=	greater than
≤	=	less than or equal to
L	=	cylinder length
O.D.	=	outside diameter

If a 110% fill is authorized, only the CG-1 device is allowed.



Example 12—5% arsine, 10% phosphine, balance hydrogen

6 References

Unless otherwise specified, the latest edition shall apply.

[1] *Code of Federal Regulations*, Title 49 CFR, Parts 100 to 180 (Transportation). Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. www.access.gpo

[2] *Transportation of Dangerous Goods Regulations*, Transport Canada, Canadian Government Publishing, Public Works and Government Services Canada, Ottawa, ON K1A 0S9, Canada. www.tc.gc.ca

[3] CGA V-7, *Standard Method of Determining Cylinder Valve Outlet Connections for Industrial Gas Mixtures*, Compressed Gas Association, Inc., Compressed Gas Association, Inc., 4221 Walney Rd., 5th Floor, Chantilly, VA 20151. www.cganet.com

[4] CGA S-1.1, *Pressure Relief Device Standards—Part 1—Cylinders for Compressed Gases*, Compressed Gas Association, Inc., 4221 Walney Rd., 5th Floor, Chantilly, VA 20151. www.cganet.com

[5] CGA P-11. *Metric Practice Guide for the Compressed Gas Industry*. Compressed Gas Association, Inc.. 4221 Walney Rd., 5th Floor, Chantilly, VA 20151. www.cganet.com

[6] CGA P-20, *Standard for the Classification of Toxic Gas Mixtures*, Compressed Gas Association, Inc., 4221 Walney Rd., 5th Floor, Chantilly, VA 20151. www.cganet.com

Appendix A—FTSC numerical code for gas classification (Normative)

1st Digit — FIRE POTENTIAL

- 0 = inert
- 1 = supports combustion (oxidizing)
- 2 = flammable in air at 68 °F (20 °C) and 1 atmosphere.
- 3 = pyrophoric
- 4 = highly oxidizing
- 5 = may decompose or polymerize and is flammable

2nd Digit — TOXICITY

- 0 = life supporting (oxygen ≥ 19.5% in simple asphyxiant)
- 1 = LC_{50} > 5000 ppm
- 2 = 200 ppm < LC_{50} ≤ 5000 ppm
- 3 = LC_{50} ≤ 200 ppm

3rd Digit — STATE OF GAS: (in the cylinder at 70° F (21° C)[1]

- 0 = noncryogenic liquefied gas (less than 500 psi) (3450 kPa)[2]—gas withdrawal
- 1 = noncryogenic liquefied gas (over 500 psi) (3450 kPa)—gas withdrawal
- 2 = liquefied gas (liquid withdrawal)[3]
- 3 = dissolved/absorbed gas
- 4 = nonliquefied gas—or cryogenic gas withdrawal (less than 500 psi) (3450 kPa)
- 5 = Europe only
- 6 = nonliquefied gas between 500 psi and 3000 psi (3450 kPa and 20 680 kPa)
- 7 = nonliquefied gas above 3001 psi and below 10 000 psi (20 690 kPa and 68 950 kPa)
- 8 = cryogenic gas (liquid withdrawal) above –400 °F(–240°C)
- 9 = cryogenic gas (liquid withdrawal) below –400 °F (–240°C)

4th Digit — CORROSIVENESS:

- 0 = noncorrosive
- 1 = nonhalogen acid forming
- 2 = basic
- 3 = halogen acid forming

1) The temperature of the cryogenic gases is always below –130 °F (–90 °C).

2) If pressure at 130°F (54°C) is over 600 psi (4140 kPa), use digit 1.

3) When separate outlet for liquid withdrawal is specified.

Appendix B—List of gases
(Normative)

FTSC Code	LC_{50} PPM	Name of gas
5130		Acetylene
1060		Air
2100		Allene
		Allylene (See Methylacetylene)
2102	7 338	Ammonia, Anhydrous
0303	30	Antimony Pentafluoride
0160		Argon
2300	20	Arsine
0303	20	Arsenic Pentafluoride
		Boron Chloride (See Boron Trichloride)
		Boron Fluoride (See Boron Trifluoride)
0203	2 541	* Boron Trichloride
0263	806	Boron Trifluoride
4303	50	* Bromine Pentafluoride
4303	180	* Bromine Trifluoride
0203	260	* Bromoacetone
0100		* Bromochlorodifluoromethane (R12B1) or (Halon 1211)
0100		* Bromochloromethane (Halon 1011)
0100		Bromodifluoromethane (HBFC-22 B1)
		Bromoethylene (See Vinyl Bromide)
		Bromomethane (See Methyl Bromide)
3100		Bromotrifluoroethylene (R113B1)
0100		Bromotrifluoromethane (R13B1 or Halon 1301)
5100	220 000	1,3 Butadiene, (Inhibited)
2100		Butane, Normal
2100		1-Butene
2100		2-Butene
0110		Carbon Dioxide
		Carbon Dioxide/Nitrous Oxide Mixture (Liquid)
		Carbon Dioxide/Oxygen Mixture (Gas)
2200		Carbon Disulfide
		Carbonic Acid (See Carbon Dioxide)
2260	3 760	Carbon Monoxide
		Carbon Oxysulfide (See Carbonyl Sulfide)
		Carbon Tetrafluoride (See Tetrafluoromethane)
		Carbonyl Chloride (See Phosgene)
0213	360	Carbonyl Fluoride
2201	1 700	Carbonyl Sulfide
4203	293	Chlorine
4303	122	Chlorine Pentafluoride
4203	299	Chlorine Trifluoride
2100		Chlorodifluoroethane (R142b)
0100		Chlorodifluoromethane (R22)
0100		Chlorodifluoromethane/Chloropentafluoroethane (Mixture) (R502)
		Chloroethane (See Ethyl Chloride)
		Chloroethylene(See Vinyl Chloride)
2100		Chlorofluoromethane (R31)
0100		Chloroheptafluorocyclobutane (RC317)
		Chloromethane(See Methyl Chloride)

Appendix B—List of gases
(Normative)

FTSC Code	LC_{50} PPM		Name of gas
0100			Chloropentafluoroethane (R115)
0100			1-Chloro-1,2,2,2-Tetrafluoroethane (R124)
0100			1-Chloro-2,2,2-Trifluoroethane (R133a)
5200	2 000		Chlorotrifluoroethylene (R1113)
0100			Chlorotrifluoromethane (R13)
2200	350		Cyanogen
0303	80		Cyanogen Chloride
2100			Cyclobutane
2100	220 000		Cyclopropane
2160			Deuterium
0213	3 120		Deuterium Chloride
0203	1 100	*	Deuterium Fluoride
2301	2		Deuterium Selenide
2201	710		Deuterium Sulfide
5360	80		Diborane
1100	27 000	*	Dibromodifluoroethane
0100		*	Dibromodifluoromethane (R12B2) (Halon 1202)
			Dibromomethane (See Methylene Bromide)
0100		*	1,2 Dibromotetrafluoroethane (R114B2) (Halon 2402)
0100		*	1,2 Dichlorodifluoroethylene (R1112a)
0100			Dichlorodifluoromethane (R12)
0100			Dichlorodifluoromethane/Difluoroethane Mixture (R500)
0200		*	1,2 Dichloroethylene (R1130)
0100		*	Dichlorofluoroemethane (R21)
0100		*	1,2 Dichlorohexafluorocyclobutane (RC316)
2100			Dichloromethane
2203	314	*	Dichlorosilane
0100		*	1,1 Dichlorotetrafluoroethane (R114a)
0100		*	Dichlorotetrafluoroethane (R114)
0100		*	2,2 Dichloro-1,1,1-Trifluoroethane (R123)
			Dicyan (See Cyanogen)
3300	10	*	Diethylzinc
2100			1,1 Difluoroethane (R152a)
2110			1,1 Difluoroethylene (R1132a)
			Difluoromethane (See Methylene Fluoride)
2102		*	Dimethylamine, Anhydrous
			Dimethyl Disulfide (See Methyl Disulfide)
2100			Dimethyl Ether
2100	>5 000	*	Dimethylsilane
			Dimethyl Sulfide (See Methyl Sulfide)
2100		*	2,2 Dimethylpropane
0303	2		Diphosgene
2110			Ethane
			Ethanethiol (See Ethyl Mercaptan)
2100		*	Ethylacetylene
2100		*	Ethyl Chloride
0303	36		Ethyldichloroarsine
2160			Ethylene
5220	2 920	*	Ethylene Oxide
2100		*	Ethyl Ether
2100			Ethyl Fluoride

Appendix B—List of gases
(Normative)

FTSC Code	LC_{50} PPM		Name of gas
2100			Ethyl Mercaptan
4343	185		Fluorine
			Fluoroform (R23) (See Trifluoromethane)
2200	622		Germane
0203			Germanium Tetrachloride
0160			Helium
			Helium/Oxygen Mixture
2300	10		Heptafluorobutyronitrile
0100			Heptafluoropropane (HFC-227 ea)
0203	470		Hexafluoroacetone
2100	>5 000		Hexafluorocyclobutene
0100			Hexafluoroethane (R116)
0100			Hexafluoropropylene (R1216)
2160			Hydrogen
0203	2 860		Hydrogen Bromide
0213	3 120		Hydrogen Chloride
5301	140		Hydrogen Cyanide
0203	1 276	*	Hydrogen Fluoride
0203	2 860		Hydrogen Iodide
2301	2		Hydrogen Selenide
2201	712		Hydrogen Sulfide
4303	120	*	Iodine Pentafluoride
0203			Iodomethane
2100			Isobutane
2100			Isobutylene
0160			Krypton
0303			Lewisite (Dichloro 2 - Chloro Vinyl Arsine)
2160			Methane
2100			Methylacetylene
0200	850	*	Methyl Bromide
2100		*	3-Methyl-1-Butene
2100	8 300		Methyl Chloride
0303			Methyldichloroarsine
2300			Methyl Disulfide
2203		*	Methylene Bromide
2110			Methyl Fluoride (R41)
2110			Methylene Fluoride (R32)
2100		*	Methyl Formate
0303		*	Methyl Iodide
2201	1 350		Methyl Mercaptan
2100	>5 000		Methylsilane
2100			Methyl Sulfide
2102		*	Monoethylamine
2102			Monomethylamine, Anhydrous
0303	4		Mustard Gas
2160			Natural Gas
0160			Neon
2300	20	*	Nickel Carbonyl
4361	115		Nitric Oxide
0160			Nitrogen
4301	115	*	Nitrogen Dioxide

Appendix B—List of gases
(*Normative*)

FTSC Code	LC_{50} PPM	Name of gas
4301		* Nitrogen Tetroxide
4160	6 700	Nitrogen Trifluoride
4301	115	Nitrogen Trioxide
0303	35	Nitrosyl Chloride
0303		Nitrosyl Fluoride
4110		Nitrous Oxide
0303		Nitryl Fluoride
0100		Octafluorocyclobutane (RC318)
0100		Octafluoropropane (R218)
4060		Oxygen
4343	2.6	Oxygen Difluoride
4330		Ozone (Dissolved in R13)
3300	10	* Pentaborane
0100		Pentafluoroethane (HFC-125)
2300	10	Pentafluoropropionitrile
4203	770	Perchloryl Fluoride
2200		Perfluorobutadiene
0100		* Perfluorobutane (FC-3-1-10)
0100	12 000	* Perfluoro-2-Butene
0303	5	Phenylcarbylamine Chloride
0303	5	Phosgene
3310	20	Phosphine
0203	255	Phosphorous Pentafluoride
0203	425	Phosphorous Trifluoride
2100		Propane
2100		Propylene
3160	19 000	Silane
0203	750	* Silicon Tetrachloride
0263	450	Silicon Tetrafluoride
5300	20	Stibine
0201	2 520	Sulfur Dioxide
0100		Sulfur Hexafluoride
0303	40	Sulfur Tetrafluoride
0200	3 020	Sulfuryl Fluoride
0100		Tetrachloromethane
0100		1,1,1,2 Tetrafluoroethane (R-134a)
5110		Tetrafluoroethylene-Inhibited (R1114)
4340		Tetrafluorohydrazine
0160		Tetrafluoromethane (R-14)
2200		* Tetramethyllead
0100		* Trichlorofluoromethane (R11)
0100		Trichloroethylene
2203	1 040	* Trichlorosilane
0100		* 1,1,1 Trichlorotrifluoroethane (R113a)
0100		* 1,1,2 Trichlorotrifluoroethane (R113)
3300	10	Triethylaluminum
3200	1 400	Triethylborane
2200	500	Trifluoroacetonitrile
0203	208	Trifluoroacetylchloride
2100		1,1,1 Trifluoroethane (R143a)
0110		Trifluoromethane (HFC-23)

Appendix B—List of gases
(Normative)

FTSC Code	LC_{50} PPM	Name of gas
4363		Trifluoromethyl Hypofluorite
0200		Trifluoromethyl Iodide
2102	7 000	* Trimethylamine
2100	>5 000	* Trimethylsilane
3300	20	Trimethylstibine
0203	213	* Tungsten Hexafluoride
0303		* Uranium Hexafluoride
5100	>5 000	* Vinyl Bromide
5100	>5 000	Vinyl Chloride
5100	>5 000	Vinyl Fluoride
5100	>5 000	Vinyl Methyl Ether
0160		Xenon

*Not a compressed gas

Appendix C—Sample worksheet
(Informative)

COMPONENTS	CONCENTRATION	F	T	S	C	LC_{50}
1.						
2.						
3.						
4.						
5.						

DOT CYLINDER RATING:

FINAL PRESSURE psig @ 70 °F
psig @ 130 °F

CYLINDER DIMENSIONS:

MIXTURE FTSC: **MIXTURE LC_{50}**

Compressed Gas Association, Inc.

For other CGA publications, visit our web site at www.cganet.com.

P-1440

COMPRESSED GAS ASSOCIATION

4221 Walney Road, 5th Floor ■ Chantilly, VA 20151-2923
(703) 788-2700 ■ FAX: (703) 961-1831 ■ E-mail: cga@cganet.com ■ Web Site: www.cganet.com

April 13, 2004

Mr. Edward Mazzullo, Director
Office of Hazardous Materials Standards
U.S. Department of Transportation
Research and Special Programs Administration
400 7th Street, SW
Washington, DC 20590

Dear Mr. Mazzullo,

The Compressed Gas Association (CGA), founded in 1913, represents over one hundred twenty member companies' world wide in the development and promotion of safety standards and safe practices in the industrial gas industry. The Association represents all facets of the industry – manufacturers, distributors, suppliers, and transporters. Through the committee system CGA creates technical specifications, safety standards, training and educational materials; and also works with government agencies to formulate responsible regulations and standards and to promote compliance with these regulations.

CGA members produce, market, and distribute industrial gases and cryogenic liquids such as acetylene, carbon dioxide, ethylene, hydrogen, nitrogen, nitrous oxide, and oxygen as well as various specialty gases, many classified as poison gases. Accordingly our members have a strong interest in domestic and international regulations governing these products and the containers in which they are shipped.

CGA publication S-1.1 – 2001 *Pressure Relief Device Standards–Part 1–Cylinders for Compressed Gases*, is referenced in 49 CFR 171.7, 173.301, 173.304a and is the standard used to describe pressure relief devices and their application for various gases and compressed gas cylinder types. As it is referenced in 49 CFR, it thereby carries a regulatory imperative.

The CGA committee responsible for managing this publication is the Pressure Relief Devices Committee and since the publication of the 2001 edition, CGA S-1.1 has been revised twice. Attached to this request is a full listing of all the changes made to the 2001 edition in the 2002 and 2003 editions.

The significant changes in the 2003 edition are:

1. Text added to define tube trailer equipment and orientation.
2. Addition of provisions for metal hydride systems.

3. Changes pressure relief device requirements to optional for certain Zone B materials.
4. Makes optional the requirement for pressure relief devices on cylinders of silane that are less that 50 liters water capacity and filled to less that 1250 psig at 70 °F.
5. Size reduction in the relieving capacity of pressure relief devices on tube trailers containing silane.

CGA respectfully requests that the 2003 edition of CGA S-1.1 be adopted in its entirety by the Department of Transportation (DOT), added to the sections previously listed and thereby carry the same regulatory imperative as CGA S-1.1 – 2001.

Please contact me with any questions you may have or for any assistance we can provide to achieve approval of our request.

Sincerely,

COMPRESSED GAS ASSOCIATION, Inc,

Roger A. Smith

Roger A. Smith
Technical Director

RS/rs
Enclosures:
S-1.1 – 2001 (4 copies)
S-1.1 – 2003 (4 copies)
List of changes to the 2001 edition

cc: Mr. Charles Hochman – DOT
Ms. Hattie Mitchell – DOT
Mr. Mark Toughiry – DOT
Ms. Sandra Webb – DOT
Mr. Carl T. Johnson, President CGA (letter only)

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
5202	2002	1.1	This standard also covers requirements for pressure relief devices for TC/DOT-4L insulated cylinders containing refrigerated (cryogenic) liquids.	This standard also covers requirements for pressure relief devices for <u>TC/DOT-4L and TC-4LM</u> insulated cylinders containing refrigerated (cryogenic) liquids.	There is no TC 4L specification.
5318	2002	2	2.19 Hazard zone D A material with a toxicity LC50 greater than 3000 ppm or less than or equal to 5000 ppm.	2.19 Hazard zone D Material with a toxicity LC50 greater than 3000 ppm <u>and</u> less than or equal to 5000 ppm.	I think the change is editorial, but important.
3219	2002	2		New text: <u>2.38.1 Front end of a tube trailer</u> <u>The end used for attaching the tractor, which would move the trailer.</u>	Define "front" from back. Revised task force reason: We have been told that without a definition there can be confusion as to whether the "front" is where the valves and controls are or if the front is where the tractor or truck is attached.
3215	2002	2		New text: <u>2.38.2 Tubes</u> Cylinders over 12 ft long.	We needed a definintion for cylinders over 12 feet long to distinguish them and their special needs from those of regular compressed gas cylinders.
3216	2002	2		New text: <u>2.38.3 Tubes, jumbo</u> <u>Tubes with a diameter 18 in (45.7 cm) or greater.</u> <u>2.38.4 Tubes, small</u> <u>Tubes with a diameter less than 18 in (45.7 cm).</u>	Define the two diameters of tubes used in tube trailers, to clarify the types when recommendations may differ.
3218	2002	2		New text: <u>2.39 Tube trailer internal relief device</u> <u>A relief device configuration used on tubes wherein the components of activation are contained within the tube or end plug of the tube.</u>	A definition of "Tube trailer internal relief device" is needed.

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
3210	2003	4		New text: 4.7 Relief devices for tubes — special considerations All tube trailers or jumbo tube trailers carrying gases with an FTSC code fire potential of 2, 3, or 5 shall be equipped with vent lines pointing upwards and attached to relief devices on the front end of the tubes when said tubes are equipped with relief devices.	Attempt to protect drivers of tube trailers carrying flammable gases.
	2002	5.4	5.4 (Intentionally left blank)	Section 5.4 removed	Section 5.4 no longer needs to be reserved.
5203	2002	5.9	5.9 Flow capacity for devices on TC/DOT-4L insulated cylinders For specification TC/DOT-4L insulated cylinders containing cryogenic liquids listed in table 3, the following requirements apply:	Now 5.8 Flow capacity for devices on CTC/DOT-4L and TC-4LM insulated cylinders For specification CTC/DOT-4L and TC-4LM insulated cylinders containing cryogenic liquids listed in Table 3, the following requirements apply:	There is no TC 4L specification.
5204	2002	5.9.3	5.9.3 For specification TC/DOT-4L cylinders, a pressure control valve shall be provided and shall have a set pressure not to exceed 1¼ times the marked service pressure of the TC/DOT-4L cylinder less 15 psi if vacuum insulation is used.	Now 5.8.3 For specification CTC/DOT-4L and TC-4LM cylinders, a pressure control valve shall be provided and shall have a set pressure not to exceed 1-1/4 times the marked service pressure of the CTC/DOT-4L and TC-4LM cylinders less 15 psi if vacuum insulation is used.	There is no TC 4L specification.

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
5205	2002	5.10.2.2	5.10.2.2 The inlet pressure of the air or gas supplied to the pressure relief device shall be not less than 100 psi (689 kPa) absolute, except that the flow test of a pressure relief valve shall be made at the flow rating pressure, and the flow test of the rupture disk for the TC/DOT-4L cylinders covered in 5.9 shall be made at the rated burst pressure of the rupture disk.	Now 5.9.2.2 The inlet pressure of the air or gas supplied to the pressure relief device shall be not less than 100 psi (689 kPa) absolute, except that the flow test of a pressure relief valve shall be made at the flow rating pressure, and the flow test of the rupture disk for the CTC/DOT-4L and TC-4LM cylinders covered in 5.8 shall be made at the rated burst pressure of the rupture disk.	There is no TC 4L specification.
1402 4730	2002	6.1.1.4	For fusible alloy samples manufactured in final form, the yield temperature shall be taken as that temperature at which the sensing element begins to sink into the sample under its own weight.	For fusible alloy samples manu-factured in final form, the yield tem-perature shall be taken as that temperature at which the sensing element, under its own weight, begins to deform the sample.	Editorial - The word "sink" implies the sensing element is above the sample and therefore the orientation must be this configuration. With temperature sensing technology, "deform" implies the orientation can vary.
1301	2002	6.2.2	For fusible plugs, tests shall be conducted to confirm the fusible alloy's resistance to extrusion except where these tests are not required per 6.2.2.2.	For fusible plugs, tests shall be conducted to confirm the fusible alloy's resistance to extrusion and leaks except where these tests are not required per 6.2.2.2.	These words were unintentionally removed and were replaced.
5198	2002	6.3.2	For TC/DOT-4L cylinders, the actual burst pressure of the disk shall not exceed 105%, and not less than 90% of its rated burst pressure.	For CTC/DOT-4L and TC-4LM cylinders, the actual burst pressure of the disk shall not exceed 105%, and not less than 90% of its rated burst pressure.	There is no TC 4L specification.
5199	2002	8.2	This examination does not apply to TC/DOT-4L cylinders.	This examination does not apply to CTC/DOT-4L or TC-4LM cylinders.	There is no TC 4L specification.
3696	2002	Table 2	3rd digit-State of gas 3 = dissolved gas	3rd digit-State of gas 3 = dissolved/absorbed gas	Make provision for metal hydride storage systems.

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
4903	2003	Table 3		New text: <u>Note 7: The statement, "device is required in only one end" does not preclude use of a second device at the other end of the cylinder or tube.</u>	In an event, pressure-operated devices (CG-1, CG-7, or CG-8) can function from either end of the tube. However, if the user intent to use their thermal degradation properties under fire conditions, it may be required to install them at both ends. This note will help the user to understand that CGA standard does not intent to prevent the use of a second device at the farther end of the tube.
5515	2003	Table 3	Deuterium Selenide - 2300 Dimethylsilane - 3100 Ethylene Oxide - 5120 Hydrogen Selenide - 2300 Methyl Fluoride - 2103 Methylsilane - 3100 Nitrogen Trifluoride - 4140 Tetrafluoroethylene-Inhibited (R1114) - 5110 Trimethylsilane - 3300 Vinyl Fluoride - 2100	Revised FTSC Codes for the following gases: Deuterium Selenide - <u>2301</u> Dimethylsilane - <u>2100</u> Ethylene Oxide - <u>5200</u> Hydrogen Selenide - <u>2301</u> Methyl Fluoride - <u>2110</u> Methylsilane - <u>2100</u> Nitrogen Trifluoride - <u>4160</u> Tetrafluoroethylene-Inhibited (R1114) - <u>5100</u> Trimethylsilane - <u>2100</u> Vinyl Fluoride - <u>5100</u>	FTSC codes were approved by the Specialty Gases Committee on 10/30/01. See PCS attachment for justification of FTSC code changes.

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
6280	2003	Table 3	Boron Trifluoride CG-4 = B CG-5 = B	Boron Trifluoride CG-4 = T CG-5 = T	The rulemaking for HM-181 in the early 1990's proposed that certain Zone B materials in Division 2.3 should have their pressure relief devices removed (prohibited) in view of their inherit toxicity. The decision was ultimately made in HM-181 to allow them to continue to be used. However, the rationale that has also supported the optional removal of a pressure relief device for compressed gas mixtures with LC50's > 200ppm also supports the optional removal the pressure relief devices for these materials. As a concomitant benefit, this would result in a degree of harmonization for the pressure relief devices in the EU where pressure relief devices are not required, and in some cases prohibited. This recommendation is in harmony with the decisions made to allow the PRD to be optionally omitted for silane & silane mixtures in cylinders with settled pressures that are less than 1250 psig at 70 degrees F. This is also supported by the discussions of risk analysis that have been integral parts of the PRD docket 95-46 task force during the last several years.

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
6281	2003	Table 3	Chlorine CG-2 = H CG-4 = C Z	Chlorine CG-2 = H T CG-4 = C Z T	The rulemaking for HM-181 in the early 1990's proposed that certain Zone B materials in Division 2.3 should have their pressure relief devices removed (prohibited) in view of their inherit toxicity. The decision was ultimately made in HM-181 to allow them to continue to be used. However, the rationale that has also supported the optional removal of a pressure relief device for compressed gas mixtures with LC50's > 200ppm also supports the optional removal the pressure relief devices for these materials. As a concomitant benefit, this would result in a degree of harmonization for the pressure relief devices in the EU where pressure relief devices are not required, and in some cases prohibited. This recommendation is in harmony with the decisions made to allow the PRD to be optionally omitted for silane & silane mixtures in cylinders with settled pressures that are less than 1250 psig at 70 degrees F. This is also supported by the discussions of risk analysis that have been integral parts of the PRD docket 95-46 task force during the last several years.
4727	2002	Table 3	Germanium Tetrafluoride-FTSC Code 0344	Removed FTSC Code for Germanium Tetrafluoride	How can the FTSC code for Germanium tetrafluoride be 0344 when the number four (4) is not one of the defined options for corrosivity? Also, I doubt that Germanium tetrafluoride is INERT (defined as 0)! The committee may wish to consider the corrosivity classification as editorial and a change could be made without convening the comittee to discuss the matter. I think that the FTSC code for GeF(subscript: 4) must be corrected even though the "inert classification" may not be considered editorial in nature.

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
5513	2003	Table 3		Add an FTSC Code of 0203 for Germanium Tetrafluoride	F: material is not flammable or oxidizing - assign 0 T: material reacts violently with water; assume production of 4 moles of HF. Use ¼ of HF LC50 value for toxicity. One fourth of 1276 is 319 PPM, therefore 2 is assigned. S: as per BOC MSDS, vp at 70 F is 235 psia, therefore 0 is assigned C: based on various MSDS's, reacts violently with water, therefore forms a halogen acid (HF). Assign a 3. (Approved by Specialty Gases Committee on 10/30/01.)

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
6282	2003	Table 3	Hexafluoroacetone CG-2 = B CG-4 = B	Hexafluoroacetone CG-2 = <u>T</u> CG-4 = <u>T</u>	The rulemaking for HM-181 in the early 1990's proposed that certain Zone B materials in Division 2.3 should have their pressure relief devices removed (prohibited) in view of their inherit toxicity. The decision was ultimately made in HM-181 to allow them to continue to be used. However, the rationale that has also supported the optional removal of a pressure relief device for compressed gas mixtures with LC50's > 200ppm also supports the optional removal the pressure relief devices for these materials. As a concomitant benefit, this would result in a degree of harmonization for the pressure relief devices in the EU where pressure relief devices are not required, and in some cases prohibited. This recommendation is in harmony with the decisions made to allow the PRD to be optionally omitted for silane & silane mixtures in cylinders with settled pressures that are less than 1250 psig at 70 degrees F. This is also supported by the discussions of risk analysis that have been integral parts of the PRD docket 95-46 task force during the last several years.
3697	2002	Table 3		Added new gas to Table 3: <u>Hydrogen absorbed in metal hydride-</u> <u>FTSC Code 2130</u>	See attachment for justification of PCS 3697.

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
6283	2003	Table 3	Hydrogen Sulfide CG-2 = B CG-4 = BC	Hydrogen Sulfide CG-2 = <u>T</u> CG-4 = <u>T</u>	The rulemaking for HM-181 in the early 1990's proposed that certain Zone B materials in Division 2.3 should have their pressure relief devices removed (prohibited) in view of their inherit toxicity. The decision was ultimately made in HM-181 to allow them to continue to be used. However, the rationale that has also supported the optional removal of a pressure relief device for compressed gas mixtures with LC50's > 200ppm also supports the optional removal the pressure relief devices for these materials. As a concomitant benefit, this would result in a degree of harmonization for the pressure relief devices in the EU where pressure relief devices are not required, and in some cases prohibited. This recommendation is in harmony with the decisions made to allow the PRD to be optionally omitted for silane & silane mixtures in cylinders with settled pressures that are less than 1250 psig at 70 degrees F. This is also supported by the discussions of risk analysis that have been integral parts of the PRD docket 95-46 task force during the last several years.
4735	2003	Table 3	Nitrogen Trifluoride-FTSC Code 4140 CG-3 = B CG-4 = B CG-5 = B	Replace symbol B with symbol T: CG-3 = <u>T</u> CG-4 = <u>T</u> CG-5 = <u>T</u>	The relief device is expected to activate under fire conditions. Under these conditions, Nitrogen Triflouride goes through partial decomposition into Flourine and Nitrogen. For Flourine with LC50<200 ppm, a device is prohibited. Nitrogen Triflouride has a coefficient of oxygen equivalency of 1.56 (compared to 1.0 for oxygen and 0.209 for air). (See attachment for further justification of PCS 4735.)

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
3759	2002	Table 3	Silane – CG 4 165 (F w disk column = B Symbol Definition for B. B. When cylinders are over 65 inches (1651 mm) long, exclusive of the neck, this device is required at both ends. For shorter cylinders, the device is required in one end only.	Change symbol under Silane: Silane–CG4 165 (F w/disk column =D New Symbol Definition for D. For tubes, this device is required at both ends. For cylinders with nominal water capacity more than 50 liter and/or with fill pressure above 1250 psig at 70 degrees F (fill density of 0.274 gms/cc), the device is required only at one end. For cylinders with nominal water capacity of 50 liter or less and with fill pressure below 1250 psig at 70 F (fill density of 0.274 gms/cc), the use of this device is not required.	See attachment for justification of PCS 3759.

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
6284	2003	Table 3	Silicon Tetrafluoride CG-4 = B CG-5 = B	Silicon Tetrafluoride CG-4 = T CG-5 = T	The rulemaking for HM-181 in the early 1990's proposed that certain Zone B materials in Division 2.3 should have their pressure relief devices removed (prohibited) in view of their inherit toxicity. The decision was ultimately made in HM-181 to allow them to continue to be used. However, the rationale that has also supported the optional removal of a pressure relief device for compressed gas mixtures with LC50's > 200ppm also supports the optional removal the pressure relief devices for these materials. As a concomitant benefit, this would result in a degree of harmonization for the pressure relief devices in the EU where pressure relief devices are not required, and in some cases prohibited. This recommendation is in harmony with the decisions made to allow the PRD to be optionally omitted for silane & silane mixtures in cylinders with settled pressures that are less than 1250 psig at 70 degrees F. This is also supported by the discussions of risk analysis that have been integral parts of the PRD docket 95-46 task force during the last several years.
4750	2003	Table 3	Definition of Symbol for A. This device is required in only one end of the cylinder regardless of length with the exception of trailer tubes in which this device is required in both ends.	Definition of Symbol for A. This device is required in only one end of the cylinder or tube regardless of length (see note 7).	CG - 1, CG - 7 and CG - 8 are pressure-operated devices designed to release the entire content of the container.

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
6287	2003	Table 3	Definition of Symbol for D. For tubes, this device is required at both ends. For cylinders with nominal water capacity more than 50 L and/or with fill pressure above 1250 psig at 70 °F (fill density of 0.274 g/cc), the device is required only at one end. For cylinders with nominal water capacity of 50 L or less and with fill pressure below 1250 psig at 70 °F (fill density of 0.274 g/cc), the use of this device is not required. 4.1.3 When pressure relief devices are required at both ends of a cylinder, each end shall have the required flow capacity.	Definition of Symbol for D. For tubes, this device is required at both ends. For cylinders with nominal water capacity more than 50 liters and/or with fill pressure above 1250 psig at 70 °F (fill density of 0.274 gms/cc), the device is required only at one end. When the devices are used at both ends of a cylinder or tube, the flow capacity of each device may be combined to meet the minimum flow capacity requirement. In no case shall the flow capacity at one end of the tube be less than 50% of the minimum flow capacity requirement. For cylinders with nominal water capacity of 50 liters or less and with fill pressure below 1250 psig at 70 °F (fill density of 0.274 gms/cc), the use of this device is not required. Modified section 4.1.3 to accommodate this PCS as follows: When pressure relief devices are required at both ends of a cylinder, each end shall have the required flow capacity, <u>except as noted in Table 3, note D.</u>	Size Reduction Justification: Using the existing formula in Section 5.5 to size the PRD is overly con-servative and therefore the device is well oversized for fire protection of the cylinder or tube. This change will still provide adequate protection in the event of fire but will reduce the size of the device and thus reduce the con-sequences of a "premature actuation event". This change will significantly reduce the user site required set back distance for tubes in silane service. Justification for Half Size at each End: In the API equation, the assumptions made are the surface of the tube at 1100 deg F and the total surface area at that temperature. These assumptions are to calculate estimate the heat flux into the tube or cylinder. In a fire incident, where only one end of the tube is exposed to fire, only a portion of the tube surface area will be elevated to high temperature and, therefore, the heat flux is reduced and only partial relief capacity will be required. Furthermore, for the pressure in the tube to reaches the PRD set point, the silane gas will be at 200 degrees F. If the gas reaches 200 F, the fuse metal at both ends would melt, allowing actuation of both devices and full relief capacity. Since the goal for silane service device should be to minimize the size of the individual device, half at each end in the optimal choice.

PCS	Edition Year	Section	Original Wording	Changed Wording	Reason for Change
5200	2002	Table 3	Definition of Symbols G. Second paragraph. An alternate pressure relief valve with a marked set pressure not to exceed 150% of the DOT service pressure may be used in lieu of the rupture disk device if the flow capacity required for relief devices on TC/DOT specification 4L insulated cylinders is provided at 120% of marked set pressure.	Definition of Symbols G. Second paragraph An alternate pressure relief valve with a marked set pressure not to exceed 150% of the DOT service pressure may be used in lieu of the rupture disk device if the flow capacity required for relief devices on CTC/DOT 4L and TC-4LM specification insulated cylinders is provided at 120% of marked set pressure.	There is no TC 4L specification.
4751	2003	Table 3	Definition of Symbol for N. For use only on cylinders over 65 in (1651 mm) long. This device is required on both ends, and each device shall be arranged to discharge upwards and unobstructed to the open air in such a manner as to prevent any impingement of escaping gas upon the containers.	New Definition of Symbol for N. This device is required in only one end of tubes. The device shall be arranged to discharge upwards and unobstructed to the open air in such a manner as to prevent any impingement of escaping gas upon the containers (see note 7).	CG - 1, CG - 7 and CG - 8 are pressure-operated devices designed to release the entire content of the container.
5201	2002	Table 6, Title	Table 6—Values of Gi and Gu for rated burst pressures of rupture disks for TC/DOT-4L cylinders	Table 6—Values of Gi and Gu for rated burst pressures of rupture disks for CTC/DOT-4L and TC-4LM cylinders	There is no TC 4L specification.
4733	2002	Figure 1		Added Flow Formula Calculations to Figure 1.	Added to show correct reference to ASME figure from the ASME Boiler Pressure Vessel Code.

Technical Justification for the Assignment of a 1500psi CG-7 PRD to Hydrogen in a Metal Hydride Storage Cylinder

1. Introduction

This discussion is limited to the application of a CG-7 PRD to a DOT 3AL cylinder of approximately 3.79 lbs. water capacity (1.72 liters) and 1000 psi (69 bar) service pressure dedicated to use in a consumer hydrogen fuel cell product.

2. Metal Hydride Storage Mechanism

The metal hydride utilized in the subject application is a type AB-2 alloy. Hydrogen molecules enter the interstitial spaces of the alloy in an exothermic reaction when the alloy is exposed to the gas under pressure during absorption. A large volume of gas can be stored in the alloy under relatively low pressures. The gas is released from the alloy in an endothermic reaction when the pressure is relieved or the temperature is increased. An obvious advantage is that efficient storage of H_2 can be achieved at low pressure (<200psi) at room temperature (60°-80°F). As the temperature is increased gaseous H_2 is released to the free space in the cylinder, increasing the pressure (see attached pressure/temperature curve) until all the H_2 is desorbed. The release of gas from the alloy cools the cylinder and slows the process, as does the increase of pressure in the free space. This results in a process that can easily be controlled by pressure and temperature.

It is immediately obvious that although the gas in the free space does follow the ideal gas laws, the metal hydride storage medium as a whole does not until all the H_2 is desorbed. The thermodynamics of a metal hydride storage system are analogous to a cryogenic gas (BLEVE). Referring again to the pressure/temperature curve it can be seen that the pressure in the vessel would remain below 500psi up to 130°F. The test pressure of the cylinder would be exceeded above 200°F and the burst pressure would be exceeded at approximately 275°F.

3. Limitations and Advantages of a CG-7 PRD

According to CGA S-1.1 paragraph 3.6.1 the limitation of a CG-7 is that it maintains the pressure in the container at a limit as determined by the set pressure of the valve, and thus does not protect against rupture of the container when the application of heat weakens the container to the point where its rupture pressure is less than the operating pressure of the device. According to CGA Safety Bulletin SB-22 aluminum cylinders are unfit for service if they have been exposed to temperatures in excess of 350°F. Referring to the attached temperature/pressure curve it should be noted that the pressure in the cylinder would actuate the PRD at approximately 225°F, releasing the free H_2. The dynamics of the heat source obviously play a major role in the outcome of the event, but in most cases, the PRD would prevent catastrophic failure of the cylinder at temperatures below the melt temperature of the metal components.

4. Risk Assessment

There are several forms of product releases where the presence of a PRD is irrelevant, such as: leaking valve or neck thread, cylinder defects, major impact and abuse. One form of product release that is also not affected by the presence of a PRD, but is worth noting, is a hole in the cylinder. Tests were conducted where similar containers of gasoline, propane and H_2 in metal hydride were impacted with a high-speed projectile in the presence of an ignition source. The

H_2 in metal hydride resulted in a small standing flame on the side of the container as opposed the resulting deflagration with the other two. In an environment with a fixed temperature the release is slowed by the cooling effect on the cylinder and the result is a steady state release over a relatively long time as opposed to a sudden release of the entire lading. Although the PRD has no relevance in this particular instance the endothermic nature of desorption of H_2 from a metal hydride does contribute to the overall safety of PRD function in an overpressure situation.

4.1 Leakage of a CG-7 PRD

The possibility of leakage of the PRD is being addressed in several ways. The vendor is addressing failure of the spring through reliability testing of the design and manufacturing process controls. Corrosion, deterioration of the seat or other parts due to atmospheric conditions and contamination of the seat will be controlled to a large degree by the purity of the lading. The system utilizing the storage cylinders demands a minimum of 99.99% pure H_2. The nature of the hydriding mechanism actually purifies the H_2 even further. An internal filter prevents contamination by the metal alloy. The valve design is one that has proven itself over many years of satisfactory service in a variety of similar applications.

4.2 Overfilling

The subject cylinder is intended for use in a consumer product but the charging and recharging will be done within the existing commercial gas infrastructure. Recharging a metal hydride requires careful regulation of temperature and pressure in a controlled environment. This is best accomplished by trained personnel and will be effected through a cylinder exchange program. In this scenario a PRD offers minimal additional protection against overfilling. The recharge cycle does offer trained personnel the opportunity to inspect the cylinder for system integrity and possible leaks.

4.3 Overheating

As pointed out earlier in this discussion the pressure within this cylinder does not follow the ideal gas laws due to the metal hydride storage mechanism. The pressure will remain well within the service pressure of the vessel in all circumstances reasonably foreseen by the regulations and standards for transport, storage and use. It is however possible to exceed the burst pressure of the cylinder by overheating to temperatures less than what might be expected in fire engulfment and therefore a PRD is required.

4.4 Fire Engulfment

Based on paragraph **4.3,** fire engulfment of an H_2/metal hydride cylinder without a PRD is a moot point. Mitigation of the hazard is only possible by fitting a PRD. Although hydrogen is a flammable gas and easily ignitable the radiant energy of a hydrogen flame is much less than other flammable gasses. The relieving PRD will contribute fuel to the existing fire but the contribution, in terms of radiant heat, would be considerable less than a hydrocarbon fuel and the hazard would certainly be less than a cylinder that fails catastrophically.

5 Conclusions

5.1 Under normal operating conditions the pressure in the storage system will be less than ½ of the service pressure of the cylinder and the PRD will not be affected.

5.2 The thermodynamics of a metal hydride storage system are more analogous to a BLEVE than a compressed gas during high heat input.

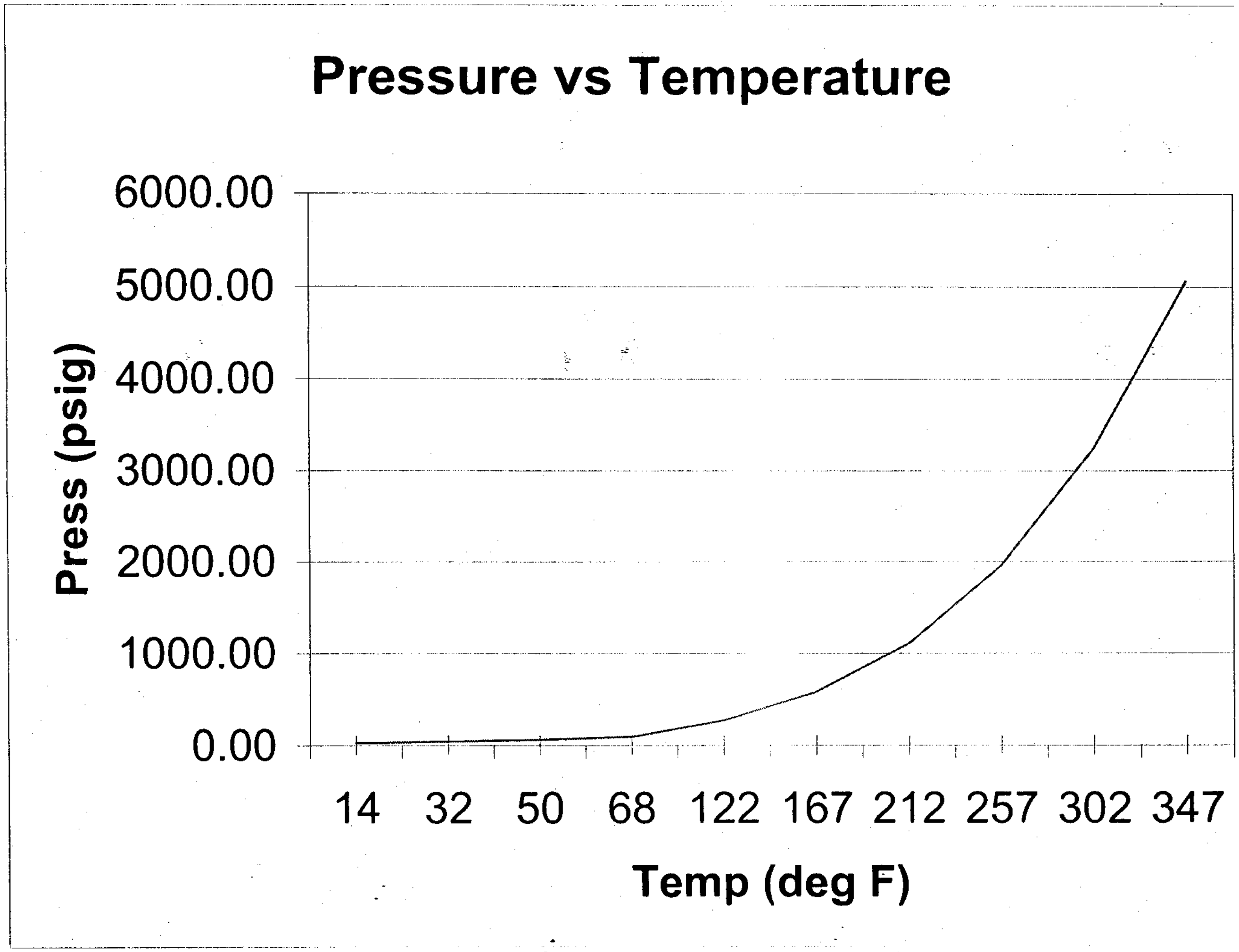
5.3 In an overheating situation characterized by steady state or gradually increasing temperature a PRD would prevent cylinder rupture.

5.4 In an overheating situation characterized by massive heat input the PRD would delay cylinder failure.

5.5 The endothermic nature of gas desorption from a metal hydride coupled with the use of a PRD can provide protection from cylinder failure at the upper extremes of the expected temperatures in normal use.

Technical Justification for the Assignment of a 1500psi CG-7 PRD to Hydrogen in a Metal Hydride Storage Cylinder

Pressure psig	Temperature (deg F)
24.76	14
39.69	32
61.53	50
92.58	68
271.00	122
575.79	167
1105.86	212
1956.78	257
3236.68	302
5061.41	347



PCS 3759 Attachment

Air Products

Air Products and Chemicals, Inc.
7201 Hamilton Blvd
Allentown, PA 18195-1501

Compressed Gas Association, Inc.
1725 Jefferson Davis Highway
Suite 1004
Arlington, VA 22202-4102

Air Products Position Statement on the Removal of Pressure Relief Devices and the Reduction of Fill Limits on DOT Cylinders in Silane Service

Question:
Should pressure relief devices (PRDs) be installed on DOT cylinders containing Silane (SiH_4) or Silane mixes? Are current fill limits acceptable?

Answer:
No. Air Products recommends that PRDs be prohibited on all DOT cylinders in Silane service and that CGA S1.1 be revised to reflect that prohibition. The prohibition should also include gas mixtures that contain more than 1.37 mole % Silane.

Air Products also recommends that current fill limits for 100% Silane be reduced. The current DOT limit states that the pressure in the container at 130° F shall not exceed 5/4 times the service pressure. That limit allows a 3AAX2400 Silane cylinder to be filled to 1680 psig at 70°F. Air Products recommends reducing the fill pressure to 1250 psig.

Reasons:
A cylinder system (cylinder, valves, PRDs) and fill limits should be designed to minimize the risk to public safety by minimizing the probability of personal injury and property damage. This safety analysis will show that the use of PRDs on cylinders in Silane service poses a greater public safety risk than the use of cylinders without PRDs. Reducing fill limits for 100% Silane will further protect the public by allowing greater evacuation time in the event of a fire and by reducing the area of impact from a deflagration or detonation.

1.0 Properties of Silane:
Silane (silicon tetrahydride, SiH_4) is a colorless pyrophoric gas. Although pyrophoric, it does not always ignite when vented to the atmosphere. Lack of instantaneous ignition can lead to accumulation and delayed ignition, resulting in fireballs (deflagration) or vapor cloud explosions (detonations).

Deflagration is an exothermic reaction, such as extremely rapid oxidation of a flammable dust of vapor in air, in which the reaction progresses through the unburned material at a rate less than the velocity of sound. A deflagration can have an explosive effect. Silane deflagration can occur from 1.37 to 96 mole % range in air. [1]

Detonation is an exothermic reaction characterized by the pressure of a shock wave in material which establishes and maintains the reaction. The reaction zone progresses through the material at a rate greater than the velocity of sound. The principal heating mechanism is one of shock compression. Detonations have an explosive effect. Silane detonation can occur from 4.5 to 25 mole % range in air. [1]

Large quantities of amorphous silica are formed during the combustion of silane. For each 1.0 lb (0.45 kg) of silane completely burned, approximately 1.8 lb (0.82 kg) of amorphous silica is formed. The stoichiometric combustion reaction of silane in air can be expressed as follows: [1]

$$SiH4 + 2O2 + N2 \rightarrow SiO2\ (s) + 2\ H2O + N2$$

2.0 Current requirements for pressure relief devices:
CGA S1.1 Pressure Relief Device Standards Part 1- Cylinders for Compressed Gases [2] assigns a CG-4 device to cylinders containing Silane. This device is a rupture disk with 165°F

fusible alloy backing and the disk is set to operate at no greater than cylinder test pressure (usually 5/3 marked service pressure).

A CG-4 fusemetal device will not prevent the rupture of a cylinder caused by overfilling, cylinder defects, corrosion, or accidents that impact, crush or puncture the cylinder wall. It is designed to only operate in an engulfing fire. It will function only if the temperature is high enough to melt the fusible metal after which excessive pressures will burst the frangible disk causing the entire contents of the cylinder to be released.

CG-4 devices will also fail to prevent the rupture of a cylinder if an intense flame impinges on and weakens the cylinder wall in a localized area away from the PRD. The weakened area can rupture before the external heat and pressure within the cylinder can trigger the relief device to function. One source of an impinging flame is Silane escaping from a failed PRD on an adjacent cylinder. Silane can produce a flame that burns from 800°F [3] to as hot as 4400°F [4].

Relief devices are **not** required and not used in countries covered by the European Industrial Gases Association (EIGA). EIGA maintains that PRDs provide minimum safety benefit and that the potential for them to inadvertently allow the release of gas in confined spaces or populated areas outweighs any advantage they may provide in preventing a cylinder from rupturing in a fire [5].

3.0 Risks Associated with inadvertent release of Silane through failed PRDs:
Inadvertent releases of Silane through failed PRDs during non-fire emergencies have the potential to cause significant personal injury and property damage. People can be exposed to hazards without prior warning, and may not have the opportunity to protect themselves from injury.

CG-4 devices are threaded mechanical devices that are subject to mechanical and physio-chemical failure. Inadvertent product release can be caused by improper handling, fusemetal extrusion, thread damage, manufacturing tolerances and defects, atmospheric corrosion, reaction with the cylinder contents, vibration or cyclic pressure fatigue, wear, incorrect installation, and damage during transportation or storage.

Since 1993, Air Products has experienced at least 4 failures of CG-4 devices in Silane service that have resulted in Emergency Responses, one at a customer site. Several smaller nuisance leaks have also occurred.

A failed relief device in a 1998 Air Products incident released an 8 foot flame that charred adjacent cylinder caps and set off the sprinkler system. The incident was caused by premature cracking of the frangible disk. Since the fusemetal backing is only designed to retain 500 psig pressure, it simply cold-flowed once the disk cracked and allowed the release of Silane. The investigation team removed CG-4 devices from 18 other Silane cylinders for analysis and found cracks in 50% of the disks removed.

Premature fusemetal extrusion is also common in Silane service. Fusemetal extrusion can occur during hot ambient storage conditions as well as during the high temperature conditioning process used to prepare the cylinders for high purity use. Extruded fusemetal provides little to no pressure retaining ability, so if a disk cracks through, the Silane has a free path for release.

The most common consequence of an inadvertent Silane release is the projection of an intense flame. Incident reports indicate flame jets projecting 6-8 feet. The projected flame has the potential to seriously injure people or impinge on adjacent cylinders, other equipment or structures and enlarge the fire. The flame will continue burning until the cylinder is empty. In one Air Products' incident, it took 2-1/2 hours for the cylinder to deplete.

If the Silane does not ignite upon initial release, it may accumulate and then ignite, creating a larger flash fire or detonation. Anything that allows confinement or pocketing of Silane can trigger these consequences. Cylinder caps and cabinets are two such areas of confinement. A small leak at a relief device can accumulate under a cylinder cap, ignite, melt the fusemetal, weaken the disk, and the release the entire contents of the cylinder.

Figures 1a and 1b show the potential areas of impact for a complete release of Silane from a 3AA2400 cylinder (9" diameter x 55" long). The figures compare a release from a 1250 psig cylinder to the release from a 1680 psig cylinder. The circular areas show the boundaries for injury from a detonation. A person located within the boundaries has an increasing potential for injury or fatality as he/she moves closer to the center of the detonation. The shaded areas show areas with the potential for a flash fire. The flash fire analysis is based on a release through a through a 0.250" diameter orifice that is dispersed per EPA's RMP alternate release scenario (atmospheric stability - D, wind speed - 3 m/s) [6].

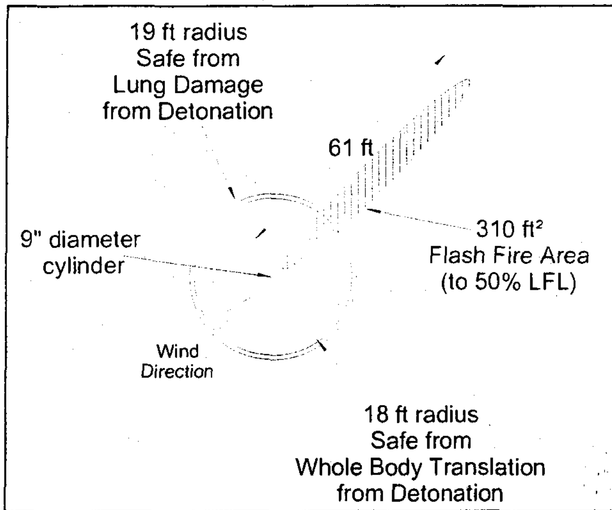


Figure 1a 1250 psig Cylinder Potential Flash Fire and Detonation Areas of Impact during Inadvertent PRD Failure

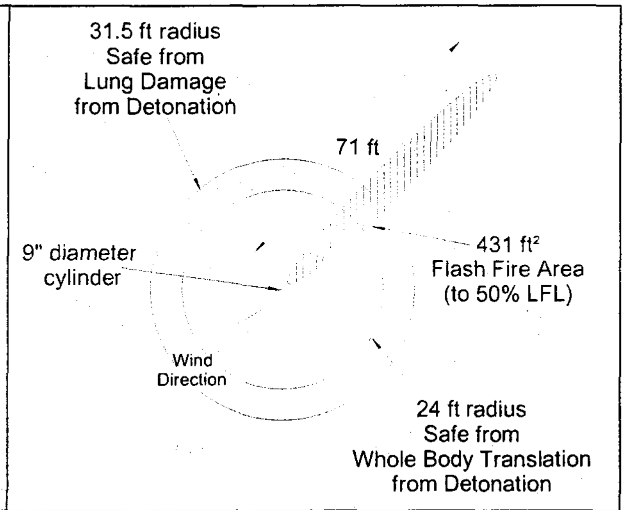


Figure 1b 1680 psig Cylinder Potential Flash Fire and Detonation Areas of Impact during Inadvertent PRD Failure

An inadvertent release from a 1680 psig cylinder has areas of impact that are much larger than a 1250 psig cylinder. The flash fire area is 39% larger, the detonation area for whole body translation is 78% larger and the detonation area for lung damage is 175% larger.

4.0 Risks Associated with the release of Silane through a PRD in an engulfing fire:
Releases of Silane through operating PRDs during fire emergencies can also cause significant personal injury and property damage.

During a fire, a properly operating PRD will burst and release the contents of the cylinder before the cylinder wall ruptures. The vessel wall may remain intact, but the PRD will burst in approximately **3.5 minutes** and release the full inventory of a 1680 psig Silane cylinder, giving people limited time to evacuate the area and protect themselves from a fireball or detonation.

The released Silane is also likely to add to the severity of the fire. The ignited Silane may impinge on nearby equipment, buildings, and cylinders, propagating the fire. Nearby heated cylinders can then release their inventories of Silane, leading to rapid escalation of the emergency and rendering control of the situation more difficult. A flame jet directed at a portion of the cylinder wall away from a PRD may also cause localized weakening the wall, leading to a cylinder rupture despite the PRD.

The propagating effect of a Silane release was apparent in a August 1997 incident at a Matheson Gas Products facility in Newark, NJ. A single Silane cylinder in a storage area leaked and the released product ignited. The adjacent Silane cylinders were heated to the point where they released Silane through the PRDs and fueled the fire. No injuries were reported, but an Emergency Response was initiated, people in the local area were evacuated, and the facility sustained over $500,000 damage[7].

5.0 Risks Associated with Cylinders not Fitted with PRDs:
The most commonly cited case for fitting a cylinder with a PRD is to prevent the rupture of a cylinder in the case of an engulfing fire. With enough heat input, the pressure of the Silane will rise and the strength of the cylinder wall material will fall until a rupture occurs. It takes a significant external fire to rupture a cylinder.

When a cylinder ruptures, two of the potential consequences (fireball and detonation) are the same as for an inadvertent release of Silane through a failed PRD. Two additional potential risks include lung damage from the rapid energy release of the expanding gas (PV blast) and impact from the projection of the cylinder or a piece of the cylinder.

Figures 2A and 2b show the potential areas of impact from a cylinder rupture during an engulfing fire. Once again, the figures compare the rupture of a 1250 psig cylinder to the rupture of a 1680 psig cylinder. A person located outside the boundaries shown is likely to survive the effects of the rupture, including lung damage from a PV blast or detonation, thermal flux from a fireball, and whole body translation from a detonation. The PV Blast is an explosion that can occur during a rupture when any high pressure gas rapidly expands to atmospheric pressure, forming a shock wave. The detonation and fireball is unique to Silane and other flammable and pyrophoric gases. Calculation methods are outlined in CCPS Book, Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs [8]. A more detailed discussion of the basis of survivability criteria is located in Appendix 1.

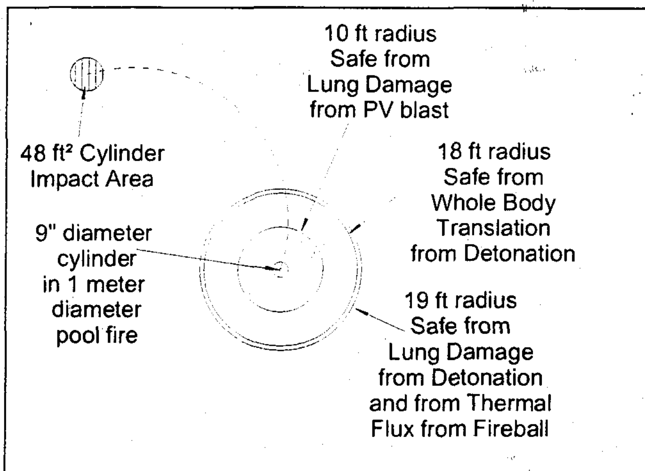


Figure 2a 1250 psig cylinder Potential Areas of Impact During a Fire (no PRD)

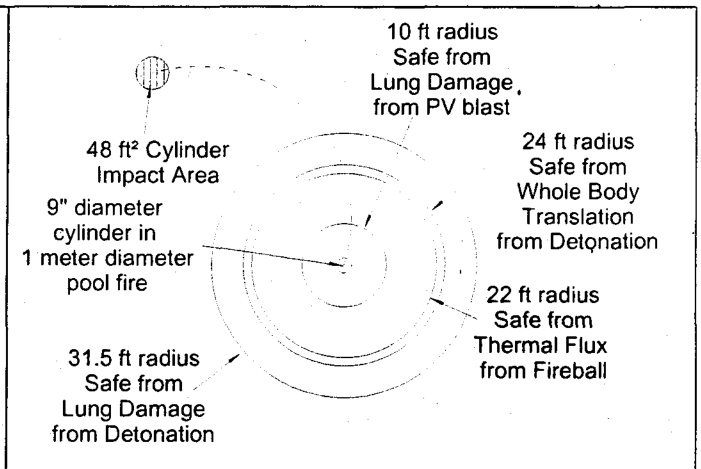


Figure 2b 1680 psig cylinder Potential Areas of Impact During a Fire (no PRD)

Figures 2a and 2b also attempt to show the maximum area of impact and the unknown impact location of a cylinder or a piece of the cylinder that may be projected over a distance. Because of the ductile nature of the materials used in the manufacture of cylinders, the most common mode of failure of a cylinder wall is the "unzipping" or "fish-mouthing" of the wall along a single longitudinal seam or the projection of one additional piece over a distance. Emergency personnel would not be exposed to multiple fragments projecting in several directions at once. Figure 3 is a photo of a typical cylinder failure.

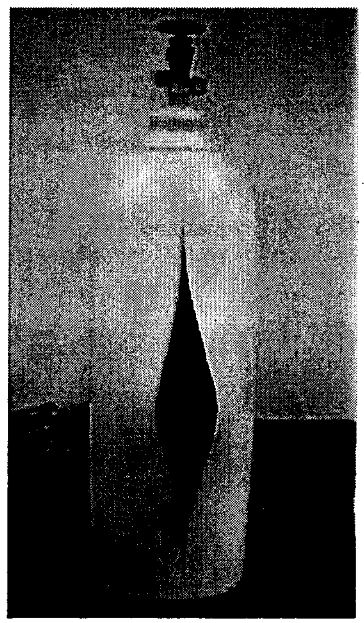


Figure 3 Typical Ductile Cylinder Failure

6.0 Probability of Silane Cylinder being exposed to an engulfing fire
The probability of a Silane cylinder being exposed to an engulfing fire during transportation is limited. Research conducted by Lawrence Livermore National Laboratory and Sandia National Laboratory [9] indicates that trucks are involved in accidents at a rate of 2.5 per million miles and fires occur in only 1.6% of all truck accidents. Given that data, Air Products, which transports Silane cylinders approximately 200,000 miles annually, would expect to be involved in a Silane truck accident with a fire once every 125 years. In addition, the severity, duration, and location of the fire may not be sufficient to rupture a cylinder.

The probability of fire engulfment at a fill plant, storage facility, or end user is also limited. Silane is a highly regulated substance, governed by several codes and standards including the Uniform Fire Code (UFC) 80-1 Storage, Dispensing, and Use of Silane and Its Mixtures, National Fire Protection Association (NFPA) 318 Standard for the Protection of Cleanrooms, and Compressed Gas Association (CGA) P-32 Safe Storage and Handling of Silane and Silane Mixtures. These documents and other local and national regulations are designed to reduce the probability of fire by specifying outdoor storage locations, minimum separation distances, proximity to flammable liquid storage, ventilation rates, barriers, gas monitoring and flame detection systems, and deluge and sprinkler systems.

7.0 Protection from Consequences of a Cylinder Rupture:
When a 3AA2400 cylinder **without a PRD** is engulfed in a fire (filled with Silane to 1250 psig at 70 F), there are **10 minutes** (see ** below) to evacuate the area to a safe location before a vessel rupture occurs. This time is reduced to 7.5 minutes when the cylinder is filled to 1680 psig. This is determined from the properties of 4140 steel and an extrapolation of the CGA fire tests (to get heat flux). It is assumed that the vessel and the Silane are at the same temperature and are uniformly heated. The non-ideal properties of Silane are accounted for using a proprietary Air Products thermodynamic properties database call CAPP (Computer Aided Physicochemical Properties).

** The ten minutes shown here is conservative and actual evacuation times will likely be greater. The length of time varies with the pressure of gas contained, cylinder wall thickness and heat transfer characteristics of cylinder wall material, presence or absence of thermal protection, characteristics of the fire – size, temperature, engulfment versus localized heating, and whether the released gas contributes to and accelerates the fire.

During this ten minutes, people will naturally be driven away from the fire surrounding the cylinders to a distance where the radiant heat is tolerable (less than 800 BTU/ft^2-hr). By modeling the fire as a point source using experimental data from the Shell Research Limited Report (Work Package No. FL1), February 1991[10], it can be determined that a person will be driven **22 feet** from a one meter diameter pool fire.

Figure 4a shows that for a cylinder filled to 1250 psig, the heat of a pool fire will drive a person out beyond the hazardous area caused by PV blast, fireball or detonation. They also have 10 minutes to find shelter or a barrier to protect themselves from the cylinder or cylinder piece that may or may not become airborne. Emergency Response teams are trained to not attempt to put out a Silane fire (to prevent delayed ignition) but instead to deluge the receptacle with water from a safe distance in order to cool it and prevent a rupture. They allow the Silane to burn until the supply is exhausted.

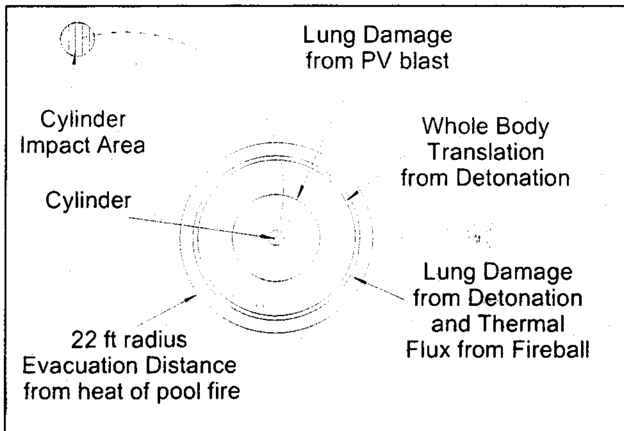


Figure 4a 1250 psig cylinder

10 minutes to evacuate. Heat from pool fire will drive people outside hazardous area for PV Blast, Fireball, and Detonation

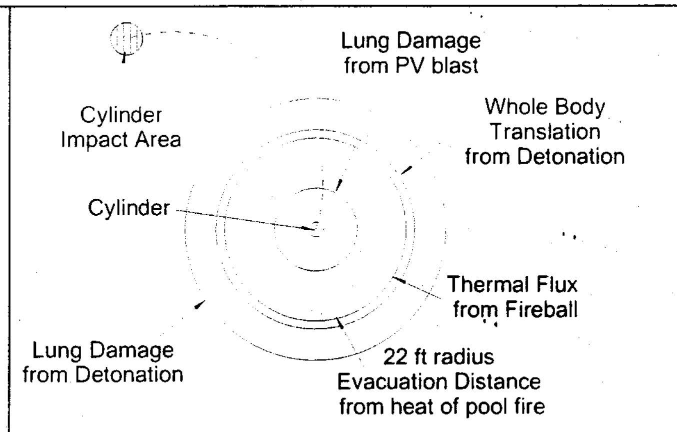


Figure 4b 1680 psig cylinder

7.5 minutes to evacuate. Heat from pool fire will drive people outside hazardous area for PV Blast and Fireball

Figure 4b shows that for a cylinder filled to 1680 psig, the heat of the pool fire will naturally drive people outside the hazardous area for PV Blast and fireball, but they might still be exposed to a detonation hazard. They will also have 2.5 minutes less time to evacuate the area.

8.0 Summary:

If the premature failure of a PRD poses a greater risk to people than the rupture of a cylinder wall, then the device should be removed. The components in the risk assessment include the relative frequency of occurrence of the event (premature relief device failure versus engulfing fire which results in vessel rupture), the consequence of the event, the area affected by the event, and the probability that someone will be inside the affected area. Table 1 summarizes these components.

Table 1 Summary
(primary figures are for a 1250 psig fill; figures for a1680 psig fill are shown in brackets [ ])

Event	Premature PRD Failure Causing Inadvertent Release of Silane	Engulfing Fire Causing Cylinder Wall Rupture
Relative Frequency of Event:	There are multiple causes for premature PRD failure. Failure rate for the complete failure of a single disk is 4.6E-7 times per year. Leaks would have a rate 10 to 100 times higher.	Less than 1 event per 25 million miles during transportation Air Products has no record of facility fires at Silane fill plants or end users that have been large enough to cause the rupture of a cylinder.
Potential Consequences:	• Flame Jet (6-8 feet) • Delayed ignition leading to deflagration (310 [431] ft² impact area) • Whole Body Translation from Detonation (18 [24] ft radius) • Lung Damage from Detonation (19 [32] ft radius) • Cascade effect (flame jet causes other PRDs to open)	• PV Blast (10 [10] ft radius) • Thermal flux injury from Fireball (19 [22] ft radius) • Whole Body Translation from Detonation (18 [24] ft radius) • Lung Damage from Detonation (19 [32] ft radius) • Projection of Cylinder or piece of cylinder
Protection from Consequences:	• Limited: Personnel will have no warning or time to protect themselves • Barrier plates may be installed that prevent failed PRDs from impinging on adjacent cylinders • Ventilation rates may prevent delayed ignition	• Time to evacuate (10 [7.5] minutes) • People driven away to safe distance by heat of fire (minimum 22 feet) • Time for Emergency Responders to cool cylinders before burst (10 [7.5] minutes) • Ductile nature of cylinder failure will prevent multiple fragments
Methods of Preventing Event from Occurring:	**Prohibit PRDs on Silane cylinders**	**Follow CGA, NFPA, and NFC storage and use rules to prevent or extinguish fires**

9.0 Conclusions:
PRDs should be prohibited from all DOT cylinders containing Silane and Silane mixtures greater than 1.37 mole % and the fill limit for a 3AA2400 cylinder containing 100% Silane should be reduced to 1250 psig at 70°F.

If 3AA2400 Silane cylinder **without a PRD** is filled to 1250 psig and then exposed to a large fire, people will be driven away from the cylinder by the heat of the fire to a distance that protects them from three hazards (PV blast , detonation, and fireball). They will also have a minimum of ten minutes to initiate evacuation procedures to protect themselves from the remaining hazard: projection of a cylinder fragment. The ductile nature of the cylinder material will limit the number of pieces to one or two.

PRDs should not be installed on DOT cylinders containing Silane because of the additional hazard of a premature PRD failure. A premature failure will release the contents of the cylinder with little or no warning. In the case of Silane, the potential area of impact is large and the chance of serious injury due to flame jet, flash fire or detonation is much greater than the chance of serious injury due to being hit by a cylinder fragment. In addition, the installed PRD will not prevent cylinder wall rupture due to non-fire cases of overpressure or localized weakening and the flame jet from a failed device can propagate and enlarge a small fire.

Reducing the fill limits on a 100% Silane 3AA2400 cylinder from 1680 psig to 1250 psig will reduce the areas of impact from a rupture up to 175% and ensure that the heat of the fire drives people outside the hazardous areas. Reducing the fill limits will also allow more time for evacuation.

The CGA prohibits PRDs on cylinders with toxic lading because the risk of premature release is greater than the risk of vessel rupture. The same logic can clearly be applied to Silane.

APPENDIX 1 – BASIS OF AREAS OF IMPACT AND SURVIVABILITY CRITERIA USED TO DETERMINE SAFE DISTANCES

The flash fire areas shown in figures 1a and 1b represent the boundary of the area that contains Silane at 50% of the lower flammability limit (LFL). 50% of LFL is recommended because of the instantaneous fluctuations in concentration that are not accounted for in the dispersion model. Pasquill-Gifford dispersion models have an implicit 10 minute averaging time whereas the ignition of a flammable cloud happens on a very short time scale. It is unlikely that the whole cloud (out to 1/2 LFL) will ignite, but individual flammable pockets within this cloud may ignite. So, the flash fire could occur in any location within the boundary shown.

For the fireball thermal flux boundaries used in figures 2a, 2b, 4a, and 4b, a thermal dosage relation (flux and duration) is used to determine the probability of survivability. The effects of radiant heat on humans is both a function of radiation intensity and duration of exposure. Eisenberg, et al (Eisenberg, et al: A Simulation System for Assessing Damage Resulting from Marine Spills, June 1975) [11], studied data on the lethality from thermal radiation and concluded that the dosage-response relationship for various probabilities of injury/fatality should be in the form,

D = t * I^(4/3) (W/sq m)^(4/3)*sec

where:
D = dosage for various probability of injury
t = duration, sec
I = thermal radiation intensity, W/m^2

The dosage used for the boundaries shown in the figures is 10.6 x 10^6, 99% survivability. The flux level was 68,700 Btu/hr-ft2, but the duration was only 0.81 seconds.

The lung damage boundaries used in figures 2a, 2b, 4a, and 4b for the PV Blast and detonation account for both the overpressure and the impulse and were selected at a point below the threshold for fatality (nearly 100% survivable). The chart in Figure 5 is taken from the CCPS book, Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs.[8] The units in this figure are dimensionless pressure on the vertical axis (overpressure/atm. pressure) and scaled impulse on the horizontal axis. The scaled impulse is defined as the impulse (overpressure integrated over the blast wave duration, Pa-s) divided by the square root of the overpressure divided by the cube root of the mass of a person (assumed 50 kg to be conservative).

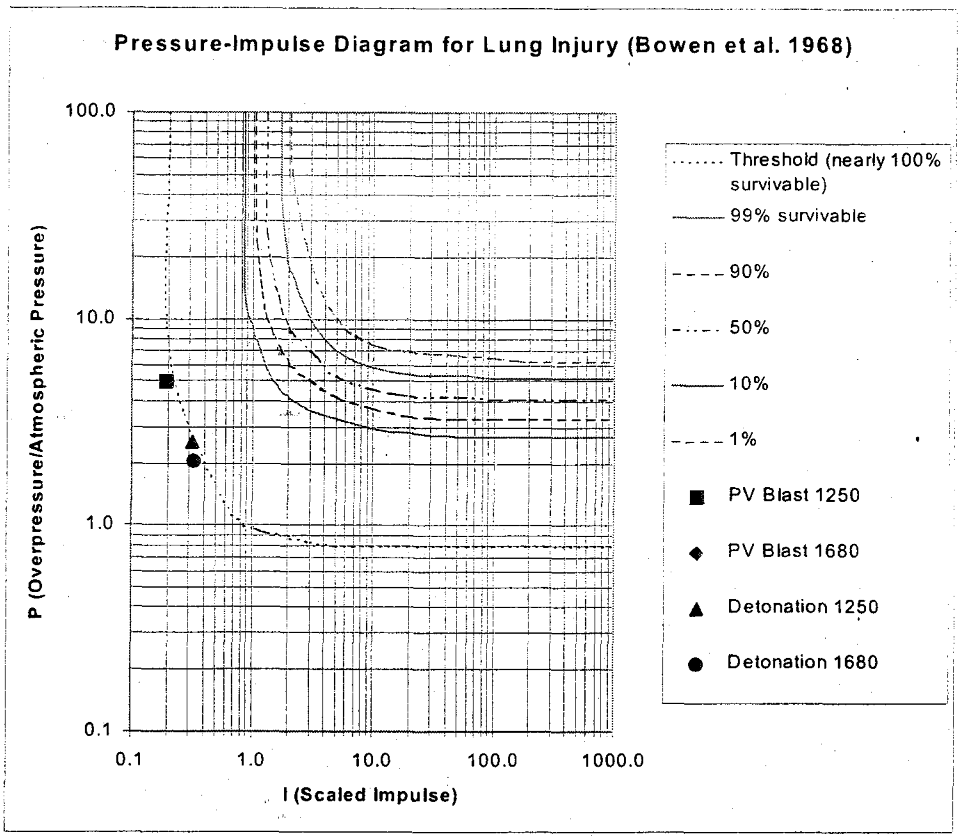


Figure 5

The tertiary effects (ie. whole body translation) boundaries used in figures 2a, 2b, 4a, and 4b for the detonation also account for both the overpressure and the impulse and were selected at a point <u>below</u> 21 ft/s impact velocity (nearly 100% survivable). The chart in Figure 6 is also taken from the CCPS book, Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs.[8] with the scale changed to English units.

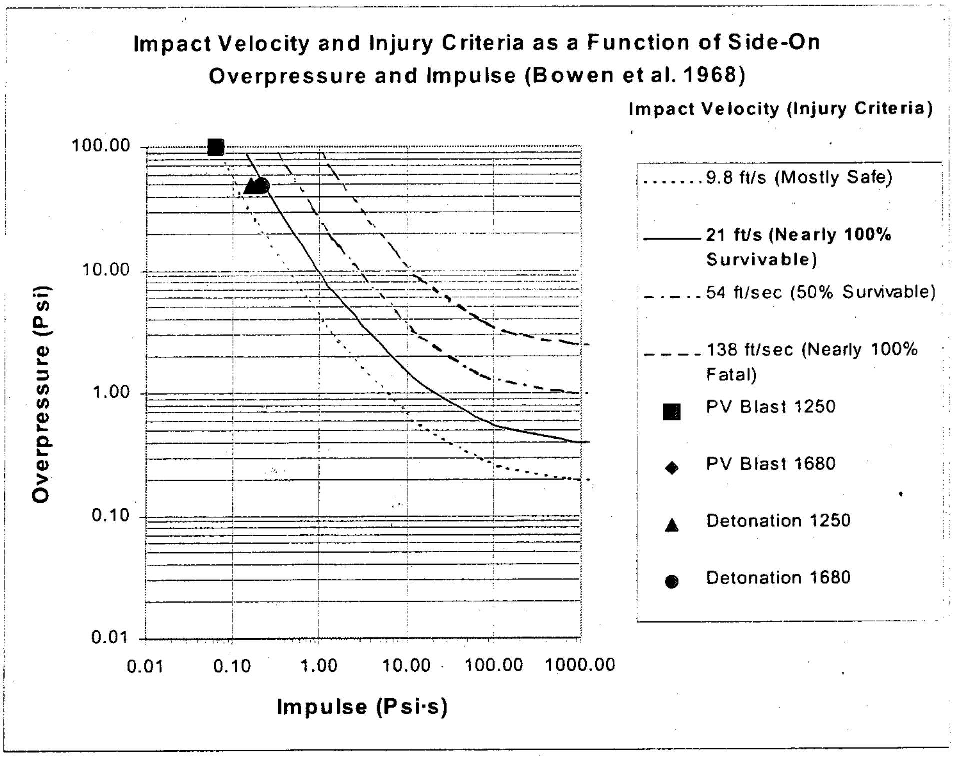


Figure 6

BIBLIOGRAPHY

[1] CGA P-32-2000, *Safe Storage and Handling of Silane and Silane Mixtures*, First Edition, Compressed Gas Association, Inc., 1725 Jefferson Davis Hwy., Suite 1004, Arlington, VA 22202

[2] CGA S 1.1, *Pressure Relief Device Standards Part 1- Cylinders for Compressed Gases*, Compressed Gas Association, Inc., 1725 Jefferson Davis Hwy., Suite 1004, Arlington, VA 22202

[3] *Silane Safety Study: Compressed Gas Association Performs Large Scale Tests*, Naser Chowdhury, SSA Journal, vol 11, 1997, pp 47-57

[4] *The History and Future of Silane as a Regulated Hazardous Material*, Stookey, S.A , Austin, TX, pp 1,2,16,20 and 21

[5] *Risk Assessment on the Use of Pressure Relief Devices on Pressure Receptacles*, Subcommittee of Experts on the Transport of Dangerous Goods, 18th Session, Geneva, 3-12 July 2000, agenda item 2.

[6] RMP Offsite Consequence Analysis Guidance, Docket A-91-73 Category VIII-A, Environmental Protection Agency, Washington, DC, May 24, 1996

[7] http://www.micromagazine.com/archive/97/10/circuit.html

[8] *Guidelines for Evaluating the Characteristics of Vapor Cloud Explosions, Flash Fires, and BLEVEs* 1994. New York: Center for Chemical Process Safety, American Institute of Chemical Engineers

[9] SAND77-0001 *Severities of Transportation Accidents Involving Large Packages.* 1978.

[10] Shell Research Limited Report (Work Package No. FL1), February 1991

[11] *A Simulation System for Assessing Damage Resulting from Marine Spills*, Eisenberg, et al, June 1975.

CGA PRD Sub-Committee

Task Force 00-66

Notes from meeting(s)

Meeting Summary 1:

Date & Time: Friday, October 20, 2000, 1:00 pm

Location: CGA Office, Washington

Attendees:

TF members: Steve Aderholt, Rich Diugosz, John Eihusen, Jerry Sameth, and Tom Joseph

Others: Bill Barlen, Bill O'Brian, and Bill Angus

Document reviewed:

APCI position statement for:

Removing PRDs from Silane and mixtures containing more than 1.37 mole % Silane and Limiting the Silane fill pressure to 1250 psig.

Discussion:

1. Silane can leak and accumulate within cylinder caps and cabinets. Lack of instantaneous ignition can result in fireballs.
2. CG-4 device will operate only in an engulfing fire. It's not protecting the cylinder from overfilling, cylinder defects, or corrosion. Also, this device will not protect cylinder from localized flame impingement.
3. PRDs are threaded mechanical devices that are subjected to mechanical and physio-chemical failure. Inadvertent release of Silane can project an intense flame upto 6-8 feet from the cylinder.
4. A fully engulfed fire will activate PRD in 3.5 minutes, adding fuel to the fire, and giving people limited time to evacuate.
5. A fully engulfed (filled) cylinder without a PRD will reach burst pressure in 10 minutes. This will provide enough time to evacuate to a safe location.
6. Limited probability of Silane cylinder exposed to an engulfing fire. A Silane truck accident with a fire once every 125 years.
7. Silane is a highly regulated substance and so limited probability of fire engulfment at a fill plant, storage, or end user location.

8. APCI clarified that the study and recommendation was based on incidents at Solkatronics facility in 1998.
9. APCI will limit the discussion to cylinders. Tubes, as defined by task force 99-81, are not covered under this proposal.
10. APCI document summarized and stated the relative risk with and without PRDs.
11. 1250 psig pressure limitation is based on pressure wave impact in a blast and evacuation distance in a fire.
12. A pool fire will drive people to a distance of 22 feet, where the radiant heat is tolerable.
13. Cylinder fill pressure exceeding 1250 psig will result in a pressure wave, capable of causing lung damage, outside the 22 feet envelope.
14. The need to have Silane fills at higher pressures was acknowledged.

Comments:

1. The proposed fill density limitations for Silane will meet the following stipulations:
   a. Not exceeding service pressure at 70F
   b. Not exceeding 5/4 the service pressure at 130F
   c. Not exceeding test pressure at 149F
2. The task force could pursue a fill density where a pressure relief device can be omitted as an option and higher level where a pressure relief device would still continue to be mandated and used.
3. APCI and Matheson TriGas will meet to review compressibility data for Silane and share information that can be presented at the January 2001 PRD committee meeting.

Meeting Summary 2:

Date & Time: Friday, December 22, 2000, 9:00 am

Location: APCI Office, Allentown

Attendees:

TF members: Jerry Sameth, and Tom Joseph

Others: Renee Koeller, Elizabeth Lutostansky (both APCI)

Documents reviewed:

Notes from meeting held on October 20th, 2000 and other data used for APCI position statement.

Discussion:

1. APCI clarified that the study included both pure and mixtures of Silane.
2. Delayed ignition of Silane is possible and can cause higher property damage and severe personal injuries.
3. PRDs offer limited protection for Silane packages – only in a fully engulfed fire (questionable) when the cylinder is full.
4. Cascade effect in an event.
5. Global standards and practices are needed for safe operation and emergency response.
6. PV blast, detonation, and fireball consequences can be addressed through optional use of the device and operational controls.
7. For Silane, retention of product will help operator to control the impact of an incident.

Comments:

1. Packagers could have the option of using a device or not, at fill pressures less than or equal to 1250 psig.
2. For fill pressures above 1250 psig, use of CG-4 type device is mandatory for limiting the effect of a detonation.
3. This proposal, with a DDS, will be presented at the task force meeting on January 8th, 2001.

CGA PRD Sub-Committee

Task Force 00-66

Notes from meeting(s)

Meeting Summary 3:

Date & Time: Monday, January 08, 2001, 1:00 pm

Location: SSK, Florida

Attendees:

TF members:

Others:

Following motion was unanimously approved by the task force on 01/08/01:

Replace symbol B with AA in Table 3 for Silane. Symbol AA is defined as:

AA. When cylinders are over 65 inches long, exclusive of the neck, this device is required at both ends. For shorter cylinders with fill pressure above 1250 psig, the device is required in one end only. For shorter cylinders with fill pressure at or below 1250 psig and water volume of 50 liter or less, the use of this device is not required.

PCS 4735 Attachment

95-46
PCS 4735

AIR PRODUCTS

Memorandum

To: Tom Joseph
Dept/Loc:

From: Beth Lutostansky
Dept/Ext: EH&S - Process Safety/14097

Date: October 16, 2001

Subject: NF_3 FMEA for PRD Removal

c: Renee Koeller

A FMEA (Failure Mode and Effect Analysis) on NF_3 cylinders both with and without relief devices was completed on September 21, 2001. The definition of the risk ranking used in the FMEA follows.

The Severity (in the column labeled "S") was rated on a scale of 1 to 4, where 1 is incidental, 2 is minor, 3 is serious and 4 is major.

The Likelihood (in the column labeled "L") was also rated on a scale of 1 to 4, where 1 is unlikely, 2 is seldom, 3 is occasional and 4 is frequent.

The Severity and the Likelihood rankings are used to develop a Risk ranking before recommendations (in the column labeled "R"). The Risk ranking is defined by a matrix of the Severity and Likelihood rankings. The Risk ranking ranges from 2 to 10, where 10 is the highest level of risk.

		Severity			
		1	2	3	4
Likelihood	1	2	3	6	7
	2	3	4	7	8
	3	4	5	8	9
	4	5	6	9	10

Two FMEAs were done. The first one was for cylinders equipped with relief devices. The second one was for cylinders without relief devices. Comparing the two FMEAs should illustrate the different risks for the two scenarios.

The cylinder valve FMEAs are identical for the two scenarios. The cylinder FMEAs are identical except for the engulfing fire failure mode. In the event of an engulfing building fire, the likelihood of a release through a pressure relief device is much higher than the likelihood of a cylinder rupture for a cylinder not equipped with a relief device. The corresponding risk for the cylinder equipped with a relief device is also higher. The risk of being exposed to the toxic, oxidizing material from a relief device is greater than the risk of cylinder rupture. The third part of the FMEA for the pressure relief device is only applicable to the cylinders equipped with the relief device, adding additional risks for these cylinders.

Air Products asserts that the risks introduced by a relief device are greater than the risks introduced by having a cylinder without a relief device.

Worksheet - Cover Page

Printed: October 17, 2001, 2:43 PM
Company: Air Products and Chemicals, Inc.
Location: Generic
Facility: Generic
PHA Method: FMEA
PHA Type: Initial

Process:

NF3 cylinders

File Description:

Generic review for DOT cylinders with relief devices, as currently required

Date:

9/17/2001

Process Description:

NF3 cylinders equipped with CG-3, CG-4 or CG-5 relief devices, as currently required

Chemicals:

NF3

Purpose:

To document the hazards of NF3 cylinders with relief devices

Scope:

Includes the cylinder, the relief device, and the cylinder valve

Objectives:

Project Notes:

Review to determine effects of removing relief device on NF3 cylinders

Filters: None

Worksheet

Company: Air Products and Chemicals, Inc.
Facility: Generic

Session: (1) 9/17/2001
System: (1) Cylinder
Drawings:

Revision:

FAILURE MODES	CAUSES	EFFECTS	SAFEGUARDS	S	L	R	RECOMMENDATIONS
Corrosion	General corrosion	Leakage - Cylinder wall	Maintenance procedures	4	1	7	
			Material selection				
		Cylinder rupture	Maintenance procedures	4	1	7	
			Material selection				
	Internal corrosion	Leakage - Cylinder wall	Maintenance procedures	4	1	7	
			Material selection				
		Cylinder rupture	Maintenance procedures	4	1	7	
			Material selection				
Fire	Fire - Building	Material release through PRD	None	4	3	9q	Investigate removal of pressure relief device
		Personnel exposure to toxic oxidizing material					
		Personnel exposure to toxic materials from NF3 thermal decomposition					
	Fire - Externally applied torch	Cylinder rupture	Operating procedures	4	1	7	
	Fire - Flammable Pool	Material release through PRD	None	4	1	7	Investigate removal of pressure relief device
		Personnel exposure to toxic oxidizing material					
		Personnel exposure to toxic materials from NF3 thermal decomposition					
Overfill	Overfill	Cylinder rupture	Relief devices on fill equipment	4	1	7	
			Operating procedures				
	Ambient temperature rise	Cylinder rupture	Operating procedures - fill pressure is 1450 psig	4	1	7	
Undesired Reaction	Contamination	Cylinder rupture	Operating procedures	4	1	7	

Worksheet

Company: Air Products and Chemicals, Inc.
Facility: Generic

Session: (1) 9/17/2001
System: (4) Rupture Disk
Drawings:

Revision:

FAILURE MODES	CAUSES	EFFECTS	SAFEGUARDS	S	L	R	RECOMMENDATIONS
Leakage - installation	Incorrect installation	Personnel exposure to toxic oxidizing material without warning	Start-up procedures	3	1	6	
Leakage - mechanical damage	Improper handling	Personnel exposure to toxic oxidizing material without warning	Operating procedures	3	1	6	
	Thread damage	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	Manufacturing tolerances and defects	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	Fatigue	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	General corrosion	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	Undesired reaction	Personnel exposure to toxic oxidizing material without warning	Material selection	3	1	6	
	Wear	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	Damage during transport or storage	Personnel exposure to toxic oxidizing material without warning	Operating procedures	3	1	6	
	Premature fusemetal extrusion	Personnel exposure to toxic oxidizing material without warning	Operating procedures	3	2	7	
Spurious operation	Spurious failure	Personnel exposure to toxic oxidizing material without warning	None	3	3	8	Investigate removal of relief devices from cylinders

Worksheet

Company: Air Products and Chemicals, Inc.
Facility: Generic

Session: (1) 9/17/2001
System: (5) Cylinder Valve
Drawings:

Revision:

FAILURE MODES	CAUSES	EFFECTS	SAFEGUARDS	S	L	R	RECOMMENDATIONS
Leakage - installation	Incorrect installation	Personnel exposure to toxic oxidizing material without warning	Start-up procedures	3	1	6	
Leakage - mechanical damage	Improper handling	Personnel exposure to toxic oxidizing material without warning	Operating procedures	3	1	6	
	Thread damage	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	Manufacturing tolerances and defects	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	Diaphragm fatigue	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	General corrosion	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	Undesired reaction	Personnel exposure to toxic oxidizing material without warning	Material selection	3	1	6	
	Seat wear	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	Damage during transport or storage	Personnel exposure to toxic oxidizing material without warning	Operating procedures	3	1	6	

Worksheet - Cover Page

Printed: October 17, 2001, 2:45 PM
Company: Air Products and Chemicals, Inc.
Location: Generic
Facility: Generic
PHA Method: FMEA
PHA Type: Initial

Process:

NF3 cylinders

File Description:

Generic review for DOT cylinders without relief devices, as proposed

Date:

9/17/2001

Process Description:

NF3 cylinders without relief devices, as proposed

Chemicals:

NF3

Purpose:

To document the hazards of NF3 cylinders without relief devices

Scope:

Includes the cylinder and the cylinder valve

Objectives:

Project Notes:

Review to determine effects of removing relief devices on NF3 cylinders

Filters: None

Worksheet

Company: Air Products and Chemicals, Inc.
Facility: Generic

Session: (1) 9/17/2001 Revision:
System: (1) Cylinder
Drawings:

FAILURE MODES	CAUSES	EFFECTS	SAFEGUARDS	S	L	R	RECOMMENDATIONS
Corrosion	General corrosion	Leakage - Cylinder wall	Maintenance procedures Material selection	4	1	7	
		Cylinder rupture	Maintenance procedures Material selection	4	1	7	
	Internal corrosion	Leakage - Cylinder wall	Maintenance procedures Material selection	4	1	7	
		Cylinder rupture	Maintenance procedures Material selection	4	1	7	
Fire	Fire - Building	Cylinder rupture	Operating procedures	4	1	7	
	Fire - Externally applied torch	Cylinder rupture	Operating procedures	4	1	7	
	Fire - Flammable pool	Cylinder rupture	Operating procedures	4	1	7	
Overfill	Overfill	Cylinder rupture	Relief devices on fill equipment Operating procedures	4	1	7	
	Ambient temperature rise	Cylinder rupture	Operating procedures - fill pressure is 1450 psig	4	1	7	
Undesired Reaction	Contamination	Cylinder rupture	Operating procedures	4	1	7	
	Thermal decomposition	Cylinder rupture	Operating procedures	4	1	7	

Worksheet

Company: Air Products and Chemicals, Inc.
Facility: Generic

Session: (1) 9/17/2001
System: (4) Cylinder valve
Drawings:

Revision:

FAILURE MODES	CAUSES	EFFECTS	SAFEGUARDS	S	L	R	RECOMMENDATIONS
Leakage - installation	Incorrect installation	Personnel exposure to toxic oxidizing material without warning	Start-up procedures	3	1	6	
Leakage - mechanical damage	Improper handling	Personnel exposure to toxic oxidizing material without warning	Operating procedures	3	1	6	
	Thread damage	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	Manufacturing tolerances and defects	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	Diaphragm fatigue	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	General corrosion	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	Undesired reaction	Personnel exposure to toxic oxidizing material without warning	Material selection	3	1	6	
	Seat wear	Personnel exposure to toxic oxidizing material without warning	Maintenance procedures	3	1	6	
	Damage during transport or storage	Personnel exposure to toxic oxidizing material without warning	Operating procedures	3	1	6	

SGC FTSC TASK FORCE - WORKSHEET 5

FTSC	MATERIAL	PUB
3100	Bromotrifluoroethylene (R113B1)	S-1.1 -- 2001
2100	Bromotrifluoroethylene (R113B1)	5145 N483
	(7/23/01) Keep 3100 until No.2 resolved	
	1) MSDS's from Lancaster and Matheson-Tri Gas and a reference in Hazardous Chemicals Desk Reference indicate that the material is pyrophoric. The reference is qualitative as no autoignition temperature is listed.[Ref 1]	
	2) RAS will research autoignition temperature and compare against CGA definition	
2300	Deuterium Selenide	S-1.1 -- 2001
2301	Deuterium Selenide	5145 N483
	(7/23/01) Change to 2301	
	1) Based on review of H_2Se MSDS's, it appears that H_2Se is soluble and would create a non-halogen acid solution. D_2Se should have the same characteristics.	
	2) JH will investigate how to represent a physical value (solubility, dissociation constant, solubility constant, etc) as defining the "C" category in FTSC codes.	
	(7/23/01) H_2Se is reported to be about 1000 times as strong an acid as H_2S and H_2S has a "C" classification of "1" - therefore "1" is indicated [Ref 2]	
0100	Dibromodifluoromethane (R12B2) (Halon 1202)	S-1.1 -- 2001
0200	Dibromodifluoromethane (R12B2) (Halon 1202)	5145 N483
	(7/23/01) This appears to be a typo since we agree on the LC_{50} - keep 0100	
	LC_{50} = 27000 PPM - CGA & ISO	
3100	Dimethylsilane	S-1.1 -- 2001
2100	Dimethylsilane	5145 N483
	(7/23/01) Change to 2100	
	Based on autoignition temperature (230° C) in Gelest MSDS and CGA definition, material is not pyrophoric.	
5220	Ethylene Oxide	S-1.1 -- 2001
5200	Ethylene Oxide	5145 N483
	(7/23/01) Change to 5200	
	Agree in principle since for "S" "0" describes the material and "2" appears to be solely use based.	
2200	Germane	S-1.1 -- 2001
2300	Germane	5145 N483
	(7/23/01) Keep 2200	
	1) CGA lists an LC_{50} of 622 ppm RAT, time adj in CGA P-20. ISO 10298 lists 20 ppm by analogy with arsine. MSDS by BOC and Sigma-Aldrich lists as 1380 mg/m^3 (BOC indicates mouse), no time duration listed. The study which indicates 1380 mg/m^3 does not cite an animal but indicates a 2-hour duration. MSDS (govt?) also indicates 1380 mg/m^3 but indicates mouse.	

FTSC	MATERIAL	PUB
	2) Conversion of 1380 mg/m^3 to ppm results in an LC_{50} of 440 ppm (LC_{50} in ppm = LC_{50} in mg/m^3 x 24.45/gram molecular weight). To convert to 1-hour exposure 440 ppm is multiplied by 1.414 (P-20 Table 2) to get 622 ppm.	
2300	Hydrogen Selenide	S-1.1 -- 2001
2301	Hydrogen Selenide	5145 N483
	(7/23/01) See D_2Se for reason [Ref 3]- change to 2301	
	Based on review of MSDS's, it appears that H_2Se is soluble and would create a non-halogen acid solution	
0200	Methyl Bromide	S-1.1 -- 2001
0300	Methyl Bromide	5145 N483
	(7/23/01) This appears to be a typo since we agree on the LC_{50} - keep 0200	
	LC_{50} = 850 PPM, CGA & ISO	
2103	Methyl Fluoride	S-1.1 -- 2001
2110	Methyl Fluoride (R41)	5145 N483
	(7/23/01) Change to 2110	
	1) Change "S" to "1" based on several MSDS's that give vp at 70° F at greater that 500 pisg and greater than 35 bar.	
	2) Change "C" "3" to "0" based on APCI MSDS indicating not corrosive to skin.	
2110	Methylene Fluoride (R32)	S-1.1 -- 2001
0110	Methylene Fluoride (R32)	5145 N483
	(7/31/01) Keep 2110	
	MSDS's by Sigma-Aldrich and Praxair indicate flammable, DOT also. Praxair MSDS gives flammable limits of 12.7% to 33.4%, meets DOT definition.	
3100	Methylsilane	S-1.1 -- 2001
2100	Methylsilane	5145 N483
	(7/23/01) Change to 2100	
	1) Praxair MSDS indicates pyrophoric, Sigma-Aldrich indicates flammable.	
	2) Based on an MSDS from Gelest, which gave an autoignition temperature of 130° C and using the definition from C-7, change the material to flammable.	
4140	Nitrogen Trifluoride	S-1.1 -- 2001
4153	Nitrogen Trifluoride	5145 N483
	(7/23/01) Change to 4160	
	1) For "S" "4" is incorrect since the material is packaged at higher that 500 psig pressures and is a permanent, non-condensable gas with similar characteristics to R-14. Change to "6" which is equivalent to European "5".	
	2) There is no evidence in reviewed MSDSs (AP, BOC, Praxair, ADSG) of halogen acid forming properties. AL MSDS indicates "corrosive". Determination is made on "pure material" i.e. does not contain F^- impurities.	
	(7/23/01) Based on APCI Safetygram-28 (Ref 3)	

SGC FTSC TASK FORCE - WORKSHEET 5

FTSC	MATERIAL	PUB
0303	Nitrosyl Chloride	S-1.1 -- 2001
0203	Nitrosyl Chloride	5145 N483
	(7/23/01) This appears to be a typo since we agree on the LC_{50} - keep 0303	
	LC_{50} = 35PPM, CGA & ISO	
0100	Perfluoro-2-Butene	S-1.1 -- 2001
0200	Perfluoro-2-Butene	5145 N483
	(7/23/01) This appears to be a typo since we agree on the LC_{50} - keep 0100	
	LC_{50} = 12000 PPM, CGA & ISO	
0303	Sulfur Tetrafluoride	S-1.1 -- 2001
0203	Sulfur Tetrafluoride	5145 N483
	(7/23/01) This appears to be a typo since we agree on the LC_{50} - keep 0303	
	LC_{50} = 40 PPM, CGA & ISO	
0200	Sulfuryl Fluoride	S-1.1 -- 2001
0300	Sulfuryl Fluoride	5145 N483
	(7/23/01) This appears to be a typo since we agree on the LC_{50} - keep 0200	
	LC_{50} = 3020 PPM CGA & ISO	
5110	Tetrafluoroethylene-Inhibited (R1114)	S-1.1 -- 2001
0100	Tetrafluoroethylene (R1114)	5145 N483
	(7/23/01) Change to 5100	
	1) MSDS from H&S and AL supports "5" for flammability and stability.	
	2) Vp from MSDS - H&S = 441 psig @ 21.1°C, AL = 435 psia at 21.1° C, therefore for "S" "0" is appropriate (below 35 bar/500 psig).	
4340	Tetrafluorohydrazine	S-1.1 -- 2001
4343	Tetrafluorohydrazine	5145 N483
	(7/23/01) Hold for further review	
0110	Trifluoromethane (HFC23)	S-1.1 -- 2001
0100	Trifluoromethane (HFC23)	5145 N483
	(7/23/01) Keep 0110	
	MSDS - AP = 611.3 psig @ 70° F, BOC = 624 psia @ 70° C, MT = 649.7 psi @ 21.1° C, Praxair = 624 psig @ 70° F, all support "1" for "S".	
3100	Trimethylsilane	S-1.1 -- 2001
2100	Trimethylsilane	5145 N483
	(7/23/01) Change to 2100	
	Base on CGA definition and Gelest MSDS autoignition temp of 310° C, flammable ("2")	
0203	Tungsten Hexafluoride	S-1.1 -- 2001
0303	Tungsten Hexafluoride	5145 N483
	(7/23/01) Keep 0203	

FTSC	MATERIAL	PUB
	1) LC_{50} - CGA P-20 lists 217 ppm, estimated as 1/6 of HF(1300 ppm), ISO 10298 lists160 ppm derived from decomposition of HF, presumably 1/6 of 966 ppm. No independent LC_{50} on MSDS's.	
	2) The LC_{50} of HF is critical and upon review of the literature, the 966 ppm appears suspect while 1300 ppm is less conservative.	
	3) More work is needed on reviewing this material. Based on task force work for P-20, a LC_{50} value of 1276 PPM will be recommended. This will not change the FTSC assignment.	
2100	Vinyl Fluoride	S-1.1 -- 2001
5100	Vinyl Fluoride	5145 N483
	(7/23/01) Change to 5100	
	Based on the Matheson Data Book, material is stable only if inhibited.	
	Pyrophoric gas - A gas that will ignite spontaneously in dry or moist air at or below a temperature of 130° F (54.4° C).	
	"State of Gas" is how the material is typically packaged and shipped at 70° F (21.1° C)	
	The task force recommends that materials that are assigned a "F" of "5" (may decompose or polymerize and is flammable) has nothing to do with how they are shipped (inhibited or not) just simply do they exhibit the listed characteristics. CGA/ISO agrees with the following material classifications that carry a "5" in the "F" character:	
5100	1,3 - butadiene (CGA/ISO list as inhibited)	
5130	acetylene	
5200	chlorotrifluoroethylene	
5350	diborane	
5200	ethylene oxide	
5301	hydrogen cyanide	
5300	stibine	
5100	vinyl bromide (ISO lists as inhibited)	
5100	vinyl chloride (ISO lists as inhibited)	
5100	vinyl methyl ether (ISO lists as inhibited)	

CGA S-1.1—2003

PRESSURE RELIEF DEVICE STANDARDS PART 1— CYLINDERS FOR COMPRESSED GASES

ELEVENTH EDITION

COMPRESSED GAS ASSOCIATION, INC.
4221 Walney Road, 5th Floor
Chantilly, VA 20151
Phone: 703-788-2700
Fax: 703-961-1831
E-mail: cga@cganet.com

PLEASE NOTE:

The information contained in this document was obtained from sources believed to be reliable and is based on technical information and experience currently available from members of the Compressed Gas Association, Inc. and others. However, the Association or its members, jointly or severally, make no guarantee of the results and assume no liability or responsibility in connection with the information or suggestions herein contained. Moreover, it should not be assumed that every acceptable commodity grade, test or safety procedure or method, precaution, equipment or device is contained within, or that abnormal or unusual circumstances may not warrant or suggest further requirements or additional procedure.

This document is subject to periodic review, and users are cautioned to obtain the latest edition. The Association invites comments and suggestions for consideration. In connection with such review, any such comments or suggestions will be fully reviewed by the Association after giving the party, upon request, a reasonable opportunity to be heard. Proposed changes may be submitted via the Internet at our web site, www.cganet.com.

This document should not be confused with Federal, state, provincial, or municipal specifications or regulations; insurance requirements; or national safety codes. While the Association recommends reference to or use of this document by government agencies and others, this document is purely voluntary and not binding.

A listing of all publications, audiovisual programs, safety and technical bulletins, and safety posters is available via the Internet at our website at www.cganet.com. For more information contact CGA at Phone: 703-788-2700, ext. 799. E-mail: customerservice@cganet.com.

Docket 02-11
Pressure Relief Devices Committee

NOTE—Technical changes from the previous edition are underlined.

NOTE—Appendices A and B (Normative) are requirements.

FOREWORD

On April 16, 1981, the United States Department of Transportation promulgated new regulations to 49 CFR 173.34(d), which eliminated the need for pressure relief device approval by the Bureau of Explosives of the Association of American Railroads. It now becomes the responsibility of the individual manufacturer or shipper to conduct his own flow and/or fire tests on new pressure relief device combinations to show compliance with CGA S-1.1, C-12, and C-14, as applicable, and to retain test records of the compliance.

ELEVENTH EDITION: 2003
TENTH EDITION: 2002
NINTH EDITION: 2001
EIGHTH EDITION: 1994

4221 WALNEY ROAD, 5TH FLOOR, CHANTILLY, VA 20151
Printed in U.S.A.

Contents **Page**

Tables

Figure

Appendices

1 Introduction

1.1

This standard represents the minimum requirements for pressure relief devices considered to be appropriate and adequate for use on cylinders having capacities of 1000 lb (454 kg) of water or less. Refer also to Title 49 of the U.S. Code of Federal Regulations (49 CFR 173.34(d)) [1].[1] This standard also applies to DOT-3AX, -3AAX, and -3T cylinders having capacities over 1000 lb (454 kg) of water, and which comply with the design specifications and charging and maintenance regulations of the U.S. Department of Transportation (DOT), or the corresponding specifications and regulations of Transport Canada (TC) [1, 2]. This standard also covers requirements for pressure relief devices for CTC/DOT-4L and TC-4LM insulated cylinders containing refrigerated (cryogenic) liquids.

1.2

This standard includes Tables 1 to 6, which provide information pertaining to pressure relief devices. Table 1 contains information on the different types of pressure relief devices. Table 2 contains FTSC code classification for gases. Table 3 contains a listing of gases and their pressure relief device assignments. Table 4 contains temperature correction factors. Table 5 includes values for basic orifice factors flange taps for flow in cubic feet per minute. Table 6 contains values of G_i and G_u for rated burst pressure of rupture disks for CTC/DOT-4L and TC-4LM cylinders.

1.3

It is recognized that there are cylinders that conform to the specification requirements of DOT or TC, but are used in services beyond the jurisdiction of any of these authorities. In such cases, it is recommended that state, provincial, local, or other authorities having jurisdiction over these cylinders be guided by this standard in determining adequate pressure relief device requirements provided that the cylinders are charged and maintained in accordance with DOT or TC regulations.

1.4

It is further recognized that there may be cylinders that are used in services beyond the jurisdiction of DOT or TC that do not conform to the specification requirements of either authority. It is recommended that the authorities having jurisdiction over such cylinders be guided by this standard in determining pressure relief device requirements, provided that such cylinders are considered by the authority as having a construction at least equal to the equivalent DOT or TC specification requirements, and further provided that the cylinder shall be charged and maintained in accordance with DOT or TC requirements.

1.5

For cylinders that come within the jurisdiction of state, provincial, and local regulatory authorities, the user should check for compliance with all such regulations. A number of states and cities have pressure vessel laws and regulations that include requirements for pressure relief devices. This standard has been prepared specifically for compressed gas cylinders, and the pressure relief devices may not be acceptable unless special permission is obtained from the authority having jurisdiction.

1.6

For newly constructed cylinders that come within the jurisdiction of DOT or TC, pressure relief devices shall comply with requirements of this standard. This publication is based on minimizing the number and optimizing the types of approved pressure relief devices specified for each specific gas. It does not restrict the continued use of previously approved and installed devices unless stated otherwise in Table 3. However, if a pressure relief device is replaced, the new device shall meet the requirements of this standard.

It is the filler's responsibility to ensure that the pressure relief device is correct.

---

[1] References are shown by bracketed numbers and are listed in order of appearance in the reference section.

1.7

For pressure relief device standards for bulk transport containers and stationary storage containers, see CGA S-1.2, *Pressure Relief Device Standards—Part 2—Cargo and Portable Tanks for Compressed Gases,* and CGA S-1.3, *Pressure Relief Device Standards—Part 3—Stationary Storage Containers for Compressed Gases* [3, 4].

2 Definitions

For the purpose of this standard, the following definitions apply.

2.1 Approach channel
Passage or passages through which fluid must pass from the cylinder to reach the operating parts of the pressure relief device.

2.2 CG-10 activation time
Time for a CG-10 device to achieve its full rated flow capacity using a standardized activation test (see 6.8.1.5).

2.3 CG-10 design life
Time the CG-10 device is designed to provide operation, within its design specification, while in normal service and use.

2.4 CG-10 service life
Specific term to be applied to those devices (CG-10) that have been shown by special analysis or testing (6.8.1.8 and 6.8.1.9) to demonstrate a fixed service life within its service.

2.5 Combination rupture-disk/fusible-plug device
Rupture disk in combination with a low temperature melting material intended to prevent bursting of the disk at its predetermined bursting pressure, unless the temperature is high enough to first cause yielding or melting of the fusible material.

2.6 Compressed gas in solution
Nonliquefied compressed gas that is dissolved in a solvent (such as acetylene dissolved in acetone).

2.7 Compressed gas
Any material that exerts in the container an absolute pressure of at least 41 psi (280 kPa) (2.8 Bar) at 68° F (20 °C).[2]

2.8 Cylinders
Pressure vessels as described in 49 CFR 171.8 and applicable TC regulations [1, 2].

2.9 Discharge channel
Passage or passages beyond the operating parts of the pressure relief device through which fluid must pass to reach the atmosphere.

2.10 Flow capacity
For a pressure relief device, this is the capacity in cubic feet per minute (cubic meters per minute or cubic meters per second) of free air discharged at the required flow rating pressure.

2.11 Flow rating pressure
Inlet static pressure at which the relieving capacity of a pressure relief device is measured for rating purposes.

2.12 Free air or free gas
Air or gas measured at a pressure of 14.696 psia and at 60 °F (101.325 kPa abs at 15.6 °C).

[2] kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per CGA P-11, *Metric Practice Guide for the Compressed Gas Industry* [5].

2.13 Fusible plug device
Nonreclosing pressure relief device designed to function by the yielding or melting of a plug of fusible material at a suitable temperature.

2.14 Fusible trigger device
Nonreclosing pressure relief device designed to function by activation of a trigger incorporating a fusible material that yields, melts, or is otherwise activated by heat. The trigger activates a mechanism that permits the release of gas.

2.15 Hazard zone A
Material with a toxicity LC_{50} less than or equal to 200 ppm.

2.16 Hazard zone B
Material with a toxicity LC_{50} greater than 200 ppm and less than or equal to 1000 ppm.

2.17 Hazard zone C
Material with a toxicity LC_{50} greater than 1000 ppm and less than or equal to 3000 ppm.

2.18 Hazard zone D
Material with a toxicity LC_{50} greater than 3000 ppm and less than or equal to 5000 ppm.

2.19 Lethal concentration fifty (LC_{50})
Concentration of a substance in air, exposure to which for a specified length of time is expected to cause the death of 50% of the entire defined experimental animal population.

2.20 Liquefied compressed gas
Gas that under the charged pressure is partially liquid at a temperature of 70 °F (21.1 °C).

2.21 Nonliquefied compressed gas
Gas other than a gas in solution that under the charging pressure is entirely gaseous at a temperature of 70 °F (21.1 °C).

2.22 Pressure control valve
As used on a cryogenic cylinder, device that vents only to maintain the proper working pressure of the cylinder under normal working conditions.

2.23 Pressure opening
Orifice against which the rupture disk functions.

2.24 Pressure relief device
Pressure and/or temperature-activated device used to prevent the pressure in a normally charged cylinder from rising above a predetermined maximum, thereby preventing rupture of the cylinder when subjected to a standard fire test as required by 49 CFR 173.34(d) or 73.34(d) of the TC regulations. The term "pressure relief device" is synonymous with "safety relief device" as used by DOT or TC regulations [1, 2]. See Section 5 for further explanation of these devices.

2.25 Pressure relief valve
Type of pressure relief device designed to relieve excessive pressure and to reclose and reseal to prevent further flow of fluid from the cylinder after reseating pressure has been achieved.

2.26 Projecting-type relief device
Pressure relief device in which the body of the device has been extended to provide for exhaust ports that divert the exhaust fluid in a plane parallel to the longitudinal axis of the cylinder.

2.27 Psi, psig, or psia
"Psi" is interpreted as pounds per square inch, "psig" is pounds per square inch gauge, and "psia" refers to absolute pressure that is based on a zero reference point—the perfect vacuum.

2.28 Rated burst pressure

Maximum pressure for which a rupture disk is designed to rupture at one specific temperature within the range of 60 °F to 160 °F (15.6 °C to 71.1 °C) when in contact with the pressure opening for which it was designed when tested as required in 6.3.

2.29 Refrigerated liquid or cryogenic liquid

Liquid with a normal boiling point below −130 °F (−90 °C) at 1 atmosphere pressure absolute.

2.30 Room temperature

Any temperature within the range of 60 °F to 80 °F (15.6 °C to 26.7 °C).

2.31 Rupture disk

Operating part of a pressure relief device that when installed in the device is designed to burst at a predetermined pressure to permit the discharge of fluid.

NOTE—Such disks, usually metal, are generally of flat, preformed, reinforced, or grooved types.

2.32 Rupture disk device

Nonreclosing pressure relief device actuated by static pressure and designed to function by the bursting of a pressure-containing disk.

2.33 Set pressure

Pressure at which a pressure relief valve is set to start-to-discharge (see 4.3.2).

2.34 Start-to-discharge pressure

For a pressure relief valve or pressure control valve, the pressure at which the first bubble appears through a water seal of not over 4-in (102-mm) water column on the outlet of the pressure relief valve or pressure control valve (see 6.6).

2.35 Test pressure of the cylinder

Minimum pressure at which a cylinder must be tested as prescribed in the specifications for compressed gas cylinders by DOT or TC.

2.36 Trailer tubes

DOT/TC cylinders horizontally mounted to a chassis for over-the-road transportation. This includes DOT cylinders horizontally mounted on modular units that may be transported over the road.

2.36.1 Front end of a tube trailer

End used for attaching the tractor, which would move the trailer.

2.36.2 Tubes

Cylinders over 12 ft long.

2.36.3 Tubes, jumbo

Tubes with a diameter 18 in (45.7 cm) or greater.

2.36.4 Tubes, small

Tubes with a diameter less than 18 in (45.7 cm).

2.37 Tube trailer internal relief device

Relief device configuration used on tubes wherein the components of activation are contained within the tube or end plug of the tube.

2.38 Yield temperature

For a fusible plug, temperature at which the fusible material becomes sufficiently soft to extrude from its holder to permit the discharge of fluid when tested in accordance with 6.2.

3 Types of pressure relief devices

Types of pressure relief devices are designated as follows:

3.1 Type CG-1

A rupture disk.

3.1.1 Limitations

Since this is a pressure-operated device designed to release the entire contents of the container, there is no way of preventing the complete release of the contents, either as a result of normal functioning or premature rupture of the device.

3.2 Type CG-2

A fusible plug using a fusible alloy with a yield temperature not over 170 °F (76.7 °C) or less than 157 °F (69.4 °C). Nominal yield temperature: 165 °F (73.9 °C).

3.2.1 Limitations

Since this is a thermally operated device, it does not protect against overpressure from improper charging practices. This device releases the entire lading of the container when it functions. This device is limited to use on cylinders of 500 psig (3450 kPa) service pressure or less. This device may be used in higher service pressure cylinders provided that the product pressure does not exceed 500 psig (3450 kPa) at 68 °F (20 °C) and the device type is mandated by this standard or TC regulations.

3.3 Type CG-3

A fusible plug using a fusible alloy with a yield temperature not over 224 °F (106.7 °C) or less than 208 °F (97.8 °C). Nominal yield temperature: 212 °F (100 °C).

3.3.1 Limitations

Same as for Type CG-2 (see 3.2.1).

3.4 Type CG-4

A combination rupture-disk/fusible-plug device using a fusible alloy with a yield temperature not over 170 °F (76.7 °C) or less than 157 °F (69.4 °C). Nominal yield temperature: 165 °F (73.9 °C).

3.4.1 Limitations

Since this device is a combination device, it requires both excessive pressure and temperature to cause it to operate. This device will not function due to excessive pressure unless the fuse metal is melted out first. Such a combination device cannot prevent an improperly filled (overfilled) cylinder from rupturing due to hydrostatic pressure at room temperature or any temperature below the melting temperature of the fusible metal, as will devices that contain only a rupture disk (Type CG-1). There is no way of preventing the complete release of the contents when this device functions.

3.5 Type CG-5

A combination rupture-disk/fusible-plug device, using a fusible alloy with a yield temperature not over 224 °F (106.7 °C) or less than 208 °F (97.8 °C). Nominal yield temperature: 212 °F (100 °C).

3.5.1 Limitations

Same as for Type CG-4 (see 3.4.1).

3.6 Type CG-7

A pressure relief valve.

3.6.1 Limitations

This device maintains the pressure in the container at a limit as determined by the set pressure of the valve and thus does not protect against rupture of the container when the application of heat weakens the container to the point where its rupture pressure is less than the operating pressure of the device.

3.7 Type CG-8

A rupture disk device followed by and in series with a pressure relief valve. The piping connecting the rupture disk and pressure relief valve shall be equipped with a sensing device to indicate pressure. This system shall be designed and constructed so the receiving capacity prescribed in 5.5 is achieved and the operation of the relief valve is not impeded.

3.7.1 Limitations

This device is a pressure-actuated device. It is intended to maximize containment of the lading following release of temporary overpressure by closure of the relief valve. Prior to release, it is less likely to exhibit leakage due to the hermetic seal of the rupture disk device. It is not intended for applications in which rapid opening is required due solely to extreme rise in surrounding temperature. It is not designed to protect the cylinder from rupture during exposure to a fire.

3.8 Type CG-9

A fusible plug for use at cylinder service pressures above 500 psig (3450 kPa) using a fusible alloy with a yield temperature not over 224 °F (106.7 °C) or less than 208 °F (97.8 °C). Nominal yield temperature: 217 °F (102.7 °C).

3.8.1 Limitations

Since this is a thermally operated device, it does not protect against overpressure from improper charging practices. This device releases the entire lading of the container when it functions. It is limited to use on cylinders whose service pressure does not exceed 6 000 psig (41 400 kPa).

3.9 Type CG-10

A fusible trigger device with an activation time of less than 90 seconds at a fill pressure within the rated pressure range marked on the device, but not to exceed 6 000 psig. A CG-10 device shall be a fixed service life device with a design life not less than 20 years.

3.9.1 Limitations

Since this is a thermally operated device, it does not protect against overpressure from improper charging practices. This device releases the entire lading of the container when it functions. It is limited to use on cylinders whose service pressure is within the rated pressure range marked on the device, but not to exceed 6000 psig.

4 Application requirements for pressure relief devices

4.1 General

4.1.1

Each cylinder charged with compressed gas, unless excepted in 4.1.1.1, shall be equipped with one or more pressure relief devices complying with the application assignments of Table 3 and the other requirements of this standard. Relief devices shall be suitably checked for leaks before shipment. Cylinders that are found to be equipped with leaking or faulty relief devices shall not be shipped until proper repairs or replacement is made.

4.1.1.1

Pressure relief devices for gases or liquids meeting the DOT definition of Hazard Zone A and other gases or liquids as designated by the DOT or TC are prohibited.

4.1.2

The design, material, and location of pressure relief devices shall be suitable for the intended service. Consideration shall be given in the design and application of pressure relief devices to the effect of the resultant thrust when the device functions.

4.1.3

When pressure relief devices are required at both ends of a cylinder, each end shall have the required flow capacity, except as noted in Table 3, note D.

4.1.4

When cylinders are required to be equipped with pressure relief devices at one end only, the flow capacity of individual pressure relief devices may be combined to meet the minimum flow capacity requirement. This provision is limited to Type CG-1 and CG-7 pressure relief devices.

4.1.5

A CG-9 device, where authorized in Table 3, may be used in parallel with either a CG-1 device or CG-7 device. Where either of these combinations are used, the minimum required flow capacity shall be satisfied by the CG-1 or CG-7 device, whichever the case may be.

4.2 Rupture disk devices

When a rupture disk device is used as a pressure relief device on a compressed gas cylinder, the rated bursting pressure of the disk when tested at the specified design temperature within the range of 60 °F to 160 °F (15.6 °C to 71.1 °C) in accordance with 6.3 shall not exceed the minimum required test pressure of the cylinder with which the disk is used, except as follows:

4.2.1

For DOT-3E or TC-3E cylinders, the rated bursting pressure of the disk shall not exceed 4500 psig (31 030 kPa).

4.2.2

For DOT-39 and TC-39M cylinders, the burst pressure of the disk shall not exceed 80% of the minimum cylinder burst pressure and shall not be less than 105% of the cylinder test pressure.

4.2.3

Except as provided in 4.2.1 and 4.2.2, for rupture disks designed to have a rated burst pressure at a specific temperature greater than 60 °F (15.6 °C) but not exceeding 160 °F (71.1 °C), the corresponding rated burst pressure at room temperature shall not exceed 110% of the minimum test pressure of the cylinder with which the disk is used.

4.2.4

Rupture disk device settings authorized for low pressure cylinders for a particular gas may be used on higher pressure cylinders for the same gas provided that the product fill density and pressurization level are the same as specified for the low pressure cylinder.

4.3 Pressure relief valves

4.3.1 Flow rating pressure

The flow rating pressure shall not exceed the minimum required test pressure of the cylinder on which the pressure relief valve is installed. The flow rating pressure for pressure relief valves for DOT-39, and TC-39M cylinders shall not exceed 80% of the minimum required cylinder burst pressure.

A pressure relief valve may incorporate a fusible element to relieve the total contents at a predetermined temperature. Where both a pressure relief valve and a fusible element are allowed, the minimum required flow capacity shall be satisfied by the pressure relief valve.

4.3.2 Set pressure

The set pressure shall not be less than 75% or more than 100% of the minimum required test pressure of the cylinder on which the pressure relief valve is installed.

For liquefied gases, pressure relief valve settings authorized for low pressure cylinders for a particular gas shall be used on high pressure (over 500 psi service pressure) cylinders for the same gas.

For DOT-39 and TC-39M cylinders, the set pressure shall not exceed 80% of the minimum cylinder burst pressure and not less than 105% of the cylinder test pressure. The reseating pressure, after the start-to-discharge has been determined, shall not be less than 80% of the cylinder test pressure.

Except for DOT-39 and TC-39M cylinders, the reseating pressure for pressure relief valves shall be determined after the start-to-discharge has been established. The reseating pressure shall not be less than the pressure in a normally charged cylinder at 130 °F (54.4 °C).

4.4 Fusible plug and fusible trigger devices

4.4.1

CG-2 and CG-3 devices are permitted to be used on cylinders whose marked service pressures do not exceed 500 psig (3450 kPa). These devices may be used on higher service pressure cylinders provided that the product pressure does not exceed 500 psig (3450 kPa) at 68 °F (20 °C) and the device type is mandated by this standard or TC regulations.

4.4.2

CG-9 and CG-10 devices are permitted to be used on cylinders whose marked service pressures do not exceed 6000 psig (41 400 kPa).

4.4.3

No CG-10 device is permitted to eject internal components outside the body of the device.

4.4.4

CG-10 devices shall only be installed into service where normal exposure temperatures are from –40 °F to 180 °F.

4.5 Rupture disk/pressure relief valve devices

A CG-8 device may be used in parallel with one or more rupture disk/fusible plug devices as auxiliary overpressure protection. The CG-8 device shall be sized in accordance with 5.5. The set pressure of this device is the greater of:

- the rated burst pressure of the disk at 60 °F (15.6 °C); or
- the set pressure of the relief valve (and shall be not less than 0.75 times the cylinder test pressure).

However, the set pressure shall not exceed the cylinder test pressure. The CG-8 system shall discharge within the control cabinet of the trailer or to a location that will not impinge on personnel.

The rupture disk portion of a rupture disk/pressure relief valve device (CG-8) shall have a rated burst pressure at 60 °F (15.6 °C) between 0.75 and 1 times the cylinder test pressure.

4.6 Piping of pressure relief devices

When fittings and piping are used on either the approach channel (upstream) or discharge channel (downstream) side or both sides of a pressure relief device or devices, the fittings and piping shall be designed so that the flow capacity of the pressure relief device shall not be reduced below the capacity required for the cylinder on which the pressure relief device assembly is installed or to the extent that the operation of the device could be impaired. Fittings, piping, and the method of attachment shall be designed to withstand normal handling and the pressures developed when the device or devices function.

A shut-off valve shall not be installed between the pressure relief devices and the cylinder or in the discharge channel.

4.7 Relief devices for tubes — special considerations

All tube trailers or jumbo tube trailers carrying gases with an FTSC code fire potential of 2, 3, or 5 shall be equipped with vent lines pointing upwards and attached to relief devices on the front end of the tubes when said tubes are equipped with relief devices.

5 Design and construction requirements for pressure relief devices

5.1 General requirements

The design, material, and location of pressure relief devices shall be suitable for the intended service. In the design and application of pressure relief devices, consideration shall be given to the effect of the resultant thrust when the device functions.

To reduce the effect of the resultant thrust when the pressure relief device functions, a projected-type pressure relief device that diverts the exhaust fluid in a plane parallel to the longitudinal axis of the cylinder should be considered. This diversion of the exhaust fluid balances the thrust forces and virtually eliminates cylinders tipping over or being dangerously propelled when the pressure relief device functions.

When used with liquefied flammable ladings, pressure relief devices and valves shall be in direct contact (communication) with the vapor space of the cylinder when in normal use. Normal use is defined as the position of the cylinder during withdrawal of its contents.

***WARNING**: Pressure relief devices may not prevent rupture of a cylinder under all conditions of fire exposure. When the heat transferred to the cylinder is localized, intense, and remote to the relief device or where the fire builds rapidly such as in an explosion and is of very high intensity, the cylinder may weaken sufficiently to rupture before the relief device operates or while it is operating.*

5.2 Material, design, and construction of a pressure relief device

The material, design, and construction of a pressure relief device shall not significantly change the functioning of the device and shall not cause any harmful corrosion or deterioration of the materials. However, under certain conditions and over an extended period of time, the start-to-discharge pressure of a CG-7 device may vary from its initial set pressure within the allowable limits (see 6.6.1).

Improper maintenance and/or abuse will adversely affect the proper functioning of these devices (see Section 8).

5.3 Combination rupture-disk/fusible-plug devices

In combination rupture-disk/fusible-plug devices, the fusible metal shall be on the discharge side of the rupture disk. The fusible metal shall not be used in lieu of a gasket to seal the disk against leakage around the edges.

Gaskets shall be of a material that will not deteriorate rapidly at the maximum temperature range specified for the fusible metal.

5.4 Flow capacity of pressure relief devices (nonliquefied gas)

For uninsulated cylinders for nonliquefied gas, the minimum required flow capacity of pressure relief devices, except pressure relief valves, shall be calculated using the following formula. (For pressure relief valves, refer to 5.6 and 5.7.)

5.4.1 Customary units

Q_a = $0.154\ W_c$

Where:

Q_a = Flow capacity at 100 psia test pressure in ft^3 per minute of free air

W_c = Water capacity of the cylinder in pounds, but not less than 25 lb

NOTE—The above formula expresses flow capacity requirements equal to 70% of that which will discharge through a perfect orifice having a 0.00012 in^2 cross-section area for each pound of water capacity of the cylinder.

5.4.2 Metric (SI) units

Q_a = $9.60 \times 10^{-3}\ W_c$

Where:

Q_a = Flow capacity at 690 kPa (abs) in m^3 per minute of free air

W_c = Water capacity of the cylinder, in kilograms, but not less than 11.3 kg

NOTE—The above formula expresses the flow capacity requirements equal to 70% of that which will discharge through a perfect orifice having a 0.171 mm^2 cross-section area for each kilogram of water capacity of the cylinder.

5.5 Flow capacity of pressure relief devices (liquefied gas)

For uninsulated cylinders for liquefied gas, the minimum required flow capacity of pressure relief devices, except pressure relief valves, shall be two times that required by the formula in 5.4.1 or 5.4.2. (For pressure relief valves refer to 5.6 and 5.7; for CG-8 devices refer to 5.5.1 and 5.5.2.)

5.5.1 Customary units

The minimum orifice area of the CG-8 device (rupture disk/pressure relief valve device) including the connecting piping shall exceed the value *Ao*, but shall not exceed two times *Ao* when calculated using the following formula:

$$Ao = \frac{(.00239)(AOV)}{\sqrt{Pset}}$$

Where:

Ao = Orifice area in in^2

AOV = Cylinder outside area in ft^2

Pset = Device set pressure in psig

5.5.2 Metric units

The minimum orifice area of the CG-8 device (rupture disk/pressure relief valve device) including the connecting piping shall exceed the value *Ao*, but shall not exceed two times *Ao* when calculated using the following formula:

$$Ao = \frac{(43.53)(AOV)}{\sqrt{Pset}}$$

Where:

Ao = Orifice area in mm^2

AOV = Cylinder outside area in m^2

$Pset$ = Device set pressure in kPa

5.6 Flow capacity of pressure relief valves (nonliquefied gas)

For uninsulated cylinders for nonliquefied gas, the minimum required flow capacity of pressure relief valves shall be calculated using the following formula:

5.6.1 Customary units

Q_a = $1.54 \times 10^{-3}\ PW_c$

Where:

Q_a = Flow capacity in ft^3 per minute of free air

P = Flow rating pressure in psia

W_c = Water capacity of the cylinder in pounds but not less than 12.5 lb

5.6.2 Metric (SI) units

Q_a = $1.395 \times 10^{-5} PW_c$

Where:

Q_a = Flow capacity in m^3 per minute of free air

P = Flow rating pressure in kPa (abs)

W_c = Water capacity of the cylinder in kilograms but not less than 5.7 kg

5.7 Flow capacity of pressure relief valves (liquefied gas)

For uninsulated cylinders for liquefied gas, the minimum required flow capacity of pressure relief valves shall be two times that required by the formulas in 5.6.1 or 5.6.2.

5.8 Flow capacity for devices on CTC/DOT-4L and TC-4LM insulated cylinders

For specification CTC/DOT-4L and TC-4LM insulated cylinders containing cryogenic liquids listed in Table 3, the following requirements apply:

5.8.1

If all materials comprising a representative sample of the insulation system remain completely in place when subjected to 1200 °F (649 °C), the *U* value shall be as defined as follows, and the minimum required flow capacity of the pressure relief device(s) shall be calculated using the following formula:

$$Q_a = G_i U A^{0.82}$$

Where:

U = Total thermal conductance of cylinder insulating material in Btu/(hr • ft^2 • °F) or the metric equivalent: kJ/(h • m^2 • °C) when saturated with gaseous lading or air at atmospheric pressure, whichever is greater. The value of *U* is determined at 100 °F (37.8 °C) except when 5.8.2.2 or 5.8.2.3 apply. (*U* is equal to the thermal conductivity of the insulation divided by the thickness of the insulation).

A = Total outside surface area of the cylinder in ft^2 (m^2)

Q_a = Flow capacity in ft^3 per minute (m^3 per hour) of free air at the rated burst pressure of the rupture disk

G_i = Gas factor for insulated containers obtained from Table 6 for the gas involved.
NOTE—Be careful to select from the proper units column, Customary or Metric.

CAUTION: *The formula $Q_a = G_i U A^{0.82}$ is sensitive to units of G_i and A. Values provided by the formulas or tables for G_i are not convertible to the other unit directly since the formula or table in each unit contains different coefficients for time and area.*

5.8.2

If any material comprising a representative sample of the insulation system deteriorates or remains only partly in place when subjected to 1200 °F (649 °C), one of the following procedures shall be used to determine the minimum flow capacity requirement of the pressure relief device(s):

5.8.2.1

Use the formula for uninsulated cylinders:

$$Q_a = G_u A^{0.82}$$

Where:

Q_a and A are as defined in 5.8.1.

G_u = Gas factor for uninsulated containers obtained from Table 6 for the gas involved. (Be careful to select from the proper units column, Customary or Metric.)

CAUTION: *The formula $Q_a = G_u A^{0.82}$ is sensitive to units of G_u and A. Values provided by the formulas or tables for G_u are not convertible to the other unit directly as the formula or table in each unit contains different coefficients for time and area.*

5.8.2.2

Determine the total thermal conductance (*U*) for a representative sample of the insulation system with a 1200 °F (649 °C) external test environment. This value of *U* shall then be used in the formula in 5.8.1 to determine the minimum required flow capacity of the pressure relief device(s). The value of *U* shall be determined with the insulation saturated with gaseous lading or air at atmospheric pressure, whichever provides the greater thermal conductance.

5.8.2.3

If the insulation system is equipped with a jacket that remains in place during fire conditions, the thermal conductance U shall be determined with no insulation and a 1200 °F (649 °C) external test environment. The value of U shall be determined with gaseous lading or air at atmospheric pressure in the space between the jacket and cylinder, whichever provides the greater thermal conductance. This value of U shall then be used in the formula in 5.8.1 to determine the minimum required flow capacity of the pressure relief device(s).

5.8.2.4

An alternative procedure may be used to qualify a composite insulation, which consists of layers of several different insulations over the entire cylinder, by exposing a sample of the composite insulation to a temperature of 1600 °F (871 °C) for 30 min, and using only the layer(s) of the insulation that is unaffected in determining the value of U to be used in the formula in 5.8.1 to calculate the minimum required flow capacity of the pressure relief device(s). Such high temperature insulation shall be kept in place by an appropriate retainer (as required by the insulation) that will remain serviceable at 1600 °F (871 °C).

5.8.2.5

Perform a fire test on a full-scale cylinder, the results of which demonstrate that the pressure relief devices are capable of preventing rupture of the normally charged cylinder. See CGA C-14, *Procedures for Fire Testing of DOT Cylinders Safety Relief Device Systems*, for details on apparatus and procedures for the fire testing of DOT cylinder/pressure relief device systems [6].

5.8.3

For specification CTC/DOT-4L and TC-4LM cylinders, a pressure control valve shall be provided and shall have a set pressure not to exceed 1-1/4 times the marked service pressure of the CTC/DOT-4L and TC-4LM cylinders less 15 psi if vacuum insulation is used. The pressure control valve shall be sized to provide adequate venting capacity as determined by the following formula:

5.8.3.1 Customary units

$$Q_a = \frac{(130 - T)G_i UA}{4(1200 - T)}$$

Where:

Q_a = The flow capacity in ft^3 per minute of free air at a flow rating pressure of 120% of the set pressure of the pressure control valve

T = Temperature in degrees F (Fahrenheit) of gas with pressure at flowing conditions

G_i = Gas factor for insulated containers obtained from Table 6 for the gas involved (select from US Customary units column)

U = Total thermal conductance Btu/(hr • ft^2 • °F), determined with the insulation space saturated with gaseous lading or air at atmospheric pressure, whichever provides the greater thermal conductance. The thermal conductance is determined at the average temperature of the insulation (Alternatively, the value of U at 100 °F may be used)

A = The total outside surface area of the cylinder in ft^2

CAUTION: *The formula* $Q_a = \frac{(130 - T)G_i UA}{4(1200 - T)}$ *is sensitive to units of G_i and A. Values provided by the formulas or tables for G_i are not convertible to the other unit directly as the formula or table in each unit contains different coefficients for time and area.*

5.8.3.2 Metric (SI) units

$$Q_a = \frac{0.382(154.4 - T)G_i UA}{(649 - T)}$$

Where:

Q_a = The flow capacity in m^3 per hour of free air at a flow rating pressure of 120% of the set pressure of the pressure control valve

T = Temperature in degrees C (Celsius) of gas with pressure at flowing conditions

G_i = Gas factor for insulated containers obtained from Table 6 for the gas involved (Select from the Metric units column)

U = Total thermal conductance kJ/(h • m^2 • °C), determined with the insulation space saturated with gaseous lading or air at atmospheric pressure, whichever provides the greater thermal conductance. The thermal conductance is determined at the average temperature of the insulation (Alternatively, the value of U at 37.8 °C may be used.)

A = The total outside surface area of the cylinder in m^2

CAUTION: *The formula* $Q_a = \frac{0.382(154.4 - T)G_i UA}{(649 - T)}$ *is sensitive to units of G_i and A. Values provided by the formulas or tables for G_i are not convertible to the other unit directly as the formula or table in each unit contains different coefficients for time and area.*

5.9 Flow testing methods

The flow capacity of each design and modification of all types of pressure relief devices shall be determined by actual flow tests. Methods of conducting flow tests are given in 5.9.1 through 5.10.

5.9.1 Sample size

Three samples of each size of each device representative of standard production shall be tested at flow rating pressure. Each device shall be caused to operate either by pressure or temperature, or by a combination of such effects and not exceeding either the maximum temperature or maximum pressure for which the device was designed.

5.9.1.1 Measurement of rated flow capacity

After pressure testing and without cleaning, removing parts, or reconditioning, each pressure relief device shall be subjected to an actual flow test wherein the amount of air or gas released by the device is measured. The rated flow capacity of the device shall be the average flow capacity of the three devices, provided the individual flow capacities fall within 10% of the highest flow capacity recorded.

5.9.2 Flow test methods

Acceptable methods of flow testing shall be one of the following:

5.9.2.1

Pressure relief devices may be tested for flow capacity by testing with equipment conforming to the American Gas Association Gas Measurement Committee Report No. 3. *Orifice Metering of Natural Gas,* or ANSI/ASME PTC 25.3, *Performance Test Code-Safety and Relief Valves* [7, 8]. Where this testing method is used, such a test may be made by the manufacturer of the pressure relief device or at a qualified test laboratory. The form "Basis for Sizing of Pressure Relief Device," Appendix A, showing the results of these tests, shall be completed and retained by the manufacturer.

5.9.2.2

Air or gas shall be supplied to the pressure relief device through a supply pipe provided with a pressure gauge and a temperature measuring device for indicating or recording the pressure and temperature of the supply. Observations shall be made and recorded after steady flow conditions have been established. Test conditions need not be the same as the conditions under which the device is expected to function in service, but the following limits shall be met:

- The inlet pressure of the air or gas supplied to the pressure relief device shall be not less than 100 psi (689 kPa) absolute, except that the flow test of a pressure relief valve shall be made at the flow rating pressure, and the flow test of the rupture disk for the CTC/DOT-4L and TC-4LM cylinders covered in 5.8 shall be made at the rated burst pressure of the rupture disk. Such test may be made by the manufacturer of the pressure relief device or by a qualified test laboratory. The form "Basis for Sizing of Pressure Relief Device," Appendix A of this standard, showing the results of these tests, shall be completed and retained by the manufacturer.

5.9.2.3

Where any other method of testing is used, a record of the accuracy of the test results prepared by a competent, impartial agency should be retained by the manufacturer.

5.10 Acetylene cylinders

For acetylene cylinders, a fire test shall be used in determining pressure relief device requirements. See CGA C-12, *Qualification Procedure for Acetylene Cylinder Design,* and the paragraph on symbol F at the end of Table 3 [9].

5.11 CG-10 devices

CG-10 devices shall demonstrate compliance to all of the requirements provided in 6.8. CG-10 devices shall comply with the marking requirements of 7.7.

6 Manufacturer's tests

6.1 Test of fusible alloy

6.1.1 Yield temperature measurement

To determine the yield temperature, the following test on the alloy shall be conducted:

6.1.1.1

Select at random two samples of the fusible alloy from each batch (heat) in the form manufactured—ingot, wire, final form such as disk or pellet, etc.

6.1.1.2

For fusible alloy supplied in ingot form, two specimens, each 2 in (50.8 mm) long by approximately 1/4 in (6.4-mm) diameter shall be taken from each ingot for test purposes. For fusible alloy supplied in wire form, two specimens shall be taken from each coil; each no less than 1-1/2-in (38.1-mm) long nor longer than 2 in (50.8 mm). Each test specimen shall be positioned horizontally on two knife edges spaced apart so that the ends of the specimen overhang the knife edges by 1/2 in (12.7 mm). The supported specimens shall be immersed in a glycerine bath not closer than 1/4 in (6.4 mm) from the bottom of the container. For fusible alloy manufactured in final form see 6.1.1.3.

6.1.1.3

Two samples from a given ingot or coil of wire shall be tested at one time. The bath temperature may be raised at a rate of 5 °F (2.8 °C) per minute (maximum) up to 10 °F (5.6 °C) below the minimum yield temperature of the alloy. After the temperature has stabilized at this level, the bath temperature shall be raised at a much slower rate, not to exceed 1 °F (0.6 °C) per minute. Temperatures shall be measured using a suitable sensing device inserted in the bath between and closely adjacent to the specimens so that the sensor will be immersed at the same level as the specimens. For fusible alloy samples manufactured in final form, temperatures shall be measured by placing the sensing device in direct contact with the sample.

6.1.1.4

The yield temperature shall be taken as that temperature at which the second of the four ends of the specimens lose their rigidity and droop, and/or drooping of the sections of the two specimens between knife edges occurs. For fusible alloy samples manufactured in final form, the yield temperature shall be taken as that temperature at which the sensing element, under its own weight, begins to deform the sample. After the temperature of the bath and fusible metal has stabilized, yielding shall occur before the maximum allowable yield temperature has been exceeded.

6.2 Tests of fusible plugs and fusible trigger devices

6.2.1 Sample size

Two representative samples shall be selected at random from each lot and subjected to the tests prescribed in 6.2.2 and 6.2.3. If both samples fail to meet the requirements of 6.2.2 and 6.2.3, the lot shall be rejected. If one sample fails to meet the requirements of 6.2.2 and 6.2.3, four additional samples may be selected at random from the same lot and subjected to these tests. If any of these four additional samples fails to meet the requirements of 6.2.2 and 6.2.3, the lot shall be rejected. A lot shall constitute no more than 3000 units of new, or 3000 units of reconditioned fusible plugs or fusible trigger devices manufactured on any one day for any one temperature range of fusible material. In no case shall a lot consist of new and reconditioned fusible plugs.

6.2.2 Resistance to extrusion

For fusible plugs, tests shall be conducted to confirm the fusible alloy's resistance to extrusion and leaks except where these tests are not required per 6.2.2.2. For fusible plugs designed to be used at cylinder service pressures above 500 psig (3450 kPa), preproduction design qualification tests shall also be required before such plugs can be made on a production basis.

6.2.2.1

CG-2 and CG-3 fusible plugs for use at 500 psig (3450 kPa) maximum shall be submitted to a controlled temperature of not less than 130 °F (54.4 °C) for 24 hours with an air or gas pressure of 500 psig (3450 kPa) applied to the end exposed to the contents of the cylinder.

To pass this test, no leakage or visible extrusion of material shall be evident upon examination of the end exposed to atmospheric pressure.

6.2.2.2

CG-9 fusible plugs shall be subjected to a controlled temperature of not less than 180 °F (82.2 °C) for 24 hours and a pressure not less than 70% of the minimum test pressure of the cylinder with which the device will be used. This test is not required for fusible metal if all of the following requirements are met:

- It has been procured and used in the final form;
- It has had no work performed on it during the manufacturing process; and
- As part of the final assembled relief device, it has passed the design qualification test of 6.2.2.3.

To pass this test, no leakage or visible extrusion of material shall be evident upon examination of the end exposed to atmospheric pressure.

6.2.2.3

Qualification tests for fusible plugs for use at service pressures above 500 psig (3450 kPa) shall require that three fusible plugs, representative of production plug design, materials, and manufacturing processes, be tested at no less than 180 °F (82.2 °C) as follows:

- Specimens shall be cycle tested at a rate not to exceed 4 cycles per minute between 300 psig (2070 kPa) and 70% of the minimum test pressure of the cylinder with which the device will be used. There shall be no leakage or visible signs of fusible metal extrusion after 26 000 cycles. Volumetric expansion of fusible metal upon resolidification is a normal condition encountered during the manufacturing process and should not be construed as extrusion.

- Specimens shall be pressurized for 500 hours at 70% of the minimum test pressure of the cylinder with which the device will be used. At the end of this test, there shall be no leakage or visible signs of fusible metal extrusion.

6.2.3 Yield temperature determination

A test for determining the yield temperature of a fusible plug shall be made as follows:

6.2.3.1

Subject the plugs to an air or gas pressure of not less than 3 psi (21 kPa) applied to the end normally exposed to the contents of the cylinder.

6.2.3.1.1

While subjected to this pressure, the plugs shall be immersed in a water bath or a glycerine water bath at a temperature of not more than 5 °F (2.8 °C) below the specified minimum yield temperature and held in that temperature range for a period of at least 10 minutes.

6.2.3.1.2

The temperature of the bath shall then be raised at a rate not in excess of 1 °F (0.6 °C) per minute during which the pressure may be increased to not more than 50 lb psi (345 kPa). When the metal weakens sufficiently to produce leakage of air or gas, the temperature of the bath shall be recorded as the yield temperature of the plugs. Yielding shall occur within 10 minutes after the maximum allowable yield temperature has been reached and stabilized and yielding shall not exceed the temperature limits specified in Section 3 for that type of fusible plug.

6.2.3.2

As an alternate method, after passing the portion of the test given in 6.2.3.1.1 at a temperature of not more than 5 °F (2.8 °C) below the specified minimum yield temperature, the plugs may at once be immersed in another bath held at a temperature not exceeding the specified maximum yield temperature. If air or gas leakage occurs within 10 minutes at that temperature, the requirements have been met.

6.2.3.3

Variation in temperature within the liquid bath in which the plug is immersed for either test in 6.2.3.1 or 6.2.3.2 shall be kept to a minimum by stirring while making these tests.

6.2.4 Chlorine service

Fusible plugs to be used in chlorine service shall meet the requirements of The Chlorine Institute, Inc. See Drawing No. 112 in Chlorine Institute Pamphlet No. 17, *Packaging Plant Safety and Operational Guidelines–Revision 1* [10].

6.3 Tests of rupture disk devices

6.3.1 Rupture disk burst pressure measurement

The production of rupture disks shall be segregated into lots of not more than 3000 disks with appropriate control exercised to ensure uniformity of production. Representative samples shall be selected at random for testing to verify the rated bursting pressure. The number of samples selected shall be appropriate for the manufacturing procedures followed, but at least two samples shall be tested from each lot. Samples shall be mounted in a proper holder with a pressure opening having dimensions identical with that in the device in which it is to be used and submitted to a burst test at a temperature not lower than 60 °F (15.6 °C) nor higher than 160 °F (71.1 °C). The test pressure may be raised rapidly to 85% of the rated burst pressure, held there for at least 30 seconds, and thereafter shall be raised at a rate not in excess of 100 psi (689 kPa) per minute, until the disk bursts. The actual burst pressure of the disk shall not be in excess of its rated burst pressure and not less than 90% of its rated burst pressure.

6.3.1.1

For rupture disks for DOT-39 and TC-39M cylinders, see 4.2.2.

6.3.1.2

For CTC/DOT-4L and TC-4LM cylinders, the actual burst pressure of the disk shall not exceed 105% of its rated burst pressure and shall not be less than 90% of its rated burst pressure.

6.3.1.3

If the actual burst pressure is not within the limits prescribed above, the entire lot of rupture disks shall be rejected. If the manufacturer so desires, four more disks selected at random from the same lot may be subjected to the same test. If all four additional disks meet the requirement, the lot may be used; otherwise, the entire lot shall be rejected. Any elevated temperature determination may be arrived at by tests conducted at room temperature provided that the relation of burst pressure to different temperatures is established by test for the type of material used.

6.3.2 Rupture disk holder test

The production of rupture disk holders (that part containing the pressure opening) of 3000 or less shall be considered a lot. Two representative holders selected at random from the lot shall be assembled with proper rupture disks from an acceptable lot as tested in 6.3.1 and subjected to the burst pressure test of 6.3.1. The actual burst pressure shall not be in excess of the rated burst pressure or less than 85% of the rated burst pressure of the disk. For CTC/DOT-4L and TC-4LM cylinders, the actual burst pressure of the disk shall not exceed 105% and shall not be less than 90% of its rated burst pressure. If the actual burst pressure at a temperature not less than 60 °F (15.6 °C) or more than 160 °F (71.1 °C) is not within the above limits, the entire lot of rupture disk holders shall be rejected. If the manufacturer desires to requalify the lot, he may subject four more holders selected as above from the same lot to the same test. If all four holders meet the requirement, the lot may be used; otherwise, the entire lot shall be rejected. Any elevated temperature determinations may be arrived at by tests conducted at room temperature provided that the relation of burst pressure to different temperatures is established by test for the type of material used.

6.3.3 Combined rupture disk and holder tests

Testing of the assembled rupture disk and holder for detailed requirements specified in 6.3.1 and 6.3.2 in lieu of individual tests will be considered as complying with requirements of both 6.3.1 and 6.3.2.

6.3.4 Affect of temperature on rupture disk tests

It is recognized that the rated burst pressure of a rupture disk corresponds to only one specific design temperature within the range of 60 °F (15.6 °C) to 160 °F (71.1 °C). Note should be taken that different results will be obtained when rupture disks are tested at different temperatures. It is therefore necessary that the temperature be specified at which the rated burst pressure applies. This combination of pressure and temperature is what is used to meet the performance requirements of 6.3. (Example: 3000 psig (20 685 kPa) at 60 °F (15.6 °C); 3000 psig (20 685 kPa) at 160 °F (71.1 °C), etc.)

Room temperature testing may be used to qualify rupture disks designed for use at elevated temperatures, (Example: not exceeding 160 °F [71.1 °C] provided there is a correlation between room temperature and elevated temperature conditions as determined by prior testing).

6.4 Tests of combination rupture-disk/fusible plug pressure relief devices

6.4.1

Many rupture-disk/fusible-plug devices shall be defined as the production, not exceeding one 10-hour shift, of any one rated burst pressure and any one yield temperature. Two representative assembled devices shall be selected at random from a lot and submitted to a performance test conducted as follows:

6.4.1.1

Each assembled device shall be subjected to a pressure of 70% to 75% of the rated burst pressure of the rupture disk used and while under this pressure shall be immersed in a liquid bath held at a temperature not more than 5 °F (2.8 °C) below the minimum specified yield temperature of the fusible metal for at least 10 min. The fusible metal shall not show signs of yielding such as melting. The temperature of the bath shall then be raised at a rate not in excess of 1 °F (0.6 °C) per minute without material change in pressure. Yielding shall occur within 10 minutes after the maximum allowable yield temperature has been reached and stabilized. Yielding shall be considered as occurring when the fusible alloy starts to flow. There shall be no leakage of air or gas.

6.4.1.2

The rupture disk shall then be tested in accordance with the requirements of 6.3.1. The device may be removed from the bath for this test.

6.4.1.3

As an alternative to tests in 6.4.1.1 and 6.4.1.2, the rupture disk and fusible metal may be tested separately to requirements 6.2.3 and 6.3.1 providing the design of the device will allow for the separation of the parts and the separate tests.

6.4.1.4

If either of the two representative devices fails to meet the requirements given in 6.4.1.1, 6.4.1.2, or 6.4.1.3, the entire lot shall be rejected. If the manufacturer desires to requalify the lot, he may subject four more such devices selected at random to the same test. If all four additional devices meet the requirements, the lot may be used.

6.5 Pressure tests of rupture disk/pressure relief valve device

6.5.1

The rupture disk portion of a CG-8 shall be tested in accordance with the requirements of 6.3.1.

6.5.2

The pressure relief valve portion of a CG-8 device shall be tested in accordance with the requirements of 6.6.1.

6.6 Pressure tests of pressure relief valves

6.6.1

Each pressure relief valve, except those for DOT-39 and TC-39M cylinders, shall be subjected to an air or gas pressure test to determine that the start-to-discharge pressure is not less than 75% or more than 100% of the flow rating pressure for which the pressure relief valve is designed.

6.6.2

The production of pressure relief valves for DOT-39 and TC-39M cylinders shall be subjected to an air or gas pressure test to determine the following:

6.6.2.1

Each pressure relief valve shall be tested for leakage at the cylinder test pressure for a minimum of 30 seconds using a water seal of not over 4 in (102 mm) on the outlet of the pressure relief valve or by any other method equally as sensitive. Any valve exhibiting leakage shall be rejected.

6.6.2.2

Two pressure relief valves taken from each lot of 3000 valves or less shall be subjected to both of the following tests:

a) First, determine that the start-to-discharge pressure is not less than 105% of the cylinder test pressure and not greater than 80% of the minimum cylinder burst pressure; and

b) Second, determine that the valve is fully open before the pressure exceeds 80% of the minimum cylinder burst pressure.

If a failure occurs in either of the tests, the entire lot shall be rejected.

6.7 Testing of repaired pressure relief devices

See 8.1.3.

6.8 Performance tests for CG-10 devices

6.8.1 CG-10 device qualification tests

All performance tests shall use three new units per test unless otherwise directed in the following sections.

6.8.1.1 Thermal cycling

The pressure relief device assembly shall be thermally cycled between –40 °F and 180 °F (–40 °C and 82 °C) as follows:

a) Place an unpressurized device assembly in a fluid bath maintained at –40 °F to –44 °F (–40 °C to –42 °C) for a period of 2 hours. Within 5 minutes of the completion of this 2-hour cold soak, the device is to be transferred from the cold bath to a fluid bath maintained at 180 °F to 190 °F (82 °C to 87 °C).

b) Maintain the unpressurized device assembly in a fluid bath maintained at 180 °F to 190 °F (82 °C to 87 °C) for a period of 2 hours. Within 5 minutes of the completion of the 2-hour warm soak, the device is to be transferred from the warm bath to a fluid bath maintained at –40° F to –44 °F (–40 °C to –42 °C).

c) Repeat steps a) and b) until a total of 15 thermal cycles has been completed.

d) With the assembly tested as outlined in a), b), and c) above, resubmit the device to a fluid bath maintained at –40° F to –44 °F (–40 °C to –42 °C) for 2 hours. Remove the device from the fluid bath and cycle the pressure relief device between not more than 10% of the service pressure and not less than 100% of the service pressure for a total of 100 cycles.

Following the thermal and pressure cycling, the pressure relief device shall meet the requirements of sections 6.8.1.5 and 6.8.2.1.

6.8.1.2 Salt corrosion resistance

Nonpermanent outlet caps shall be removed. Each assembly shall be installed in accordance with the manufacturer's recommended procedure. The device shall be pressurized to 125% of the service pressure and exposed for 144 hours to a salt spray (fog) test as specified in ASTM B117, *Standard Practice for Operating Salt Spray (Fog) Apparatus*, except that in the test of one unit, the pH of the salt solution shall be adjusted to 4.0 ± 0.2 by the addition of sulfuric acid and nitric acid in a 2:1 ratio, and in the test of the other unit, the pH of the salt solution shall be adjusted to 10.0 ± 0.2 by the addition of sodium hydroxide [11]. Additionally, both salt solutions shall be aerated to provide oxygen and carbon dioxide.

Following the salt corrosion resistance test, the pressure relief device shall meet the requirements of 6.8.1.5 and 6.8.2.1.

6.8.1.3 Stress corrosion cracking resistance

For pressure relief devices containing components made of a copper alloy, one unit shall be tested as an assembly so the copper alloy components are subjected to the stresses normally imposed on them as a result of assembly. All copper alloy components shall be degreased and then continuously exposed for 10 days to a moist ammonia/air mixture maintained in a glass chamber not larger than 12 in (305 mm) on a side and having a glass cover. Approximately 600 ml of aqueous ammonia having a specific gravity of 0.90 shall be maintained at the bottom of the glass chamber below the samples. The samples shall be positioned 1.5 in (38 mm) above the aqueous ammonia solution and supported in an inert tray. The moist ammonia/air mixture shall be maintained at atmospheric pressure with the temperature constant at 93°F ± 4°F (34°C ± 2°C). Copper alloy components shall not exhibit cracking or delamination due to this test.

Following the stress corrosion cracking resistance test, the pressure relief device shall meet the requirements of 6.8.1.5 and 6.8.2.1.

6.8.1.4 Vibration

The relief device shall be vibrated for 2 hours in each of 3 orthogonal axes at a frequency of 17 cycles per second (±5%) and an amplitude of 0.06 in (1.5 mm). Following vibration testing, the pressure relief device shall meet the requirements of 6.8.1.5 and 6.8.2.1.

6.8.1.5 Activation time

The test setup shall be in accordance with CGA C-14 except that a test vessel need not be attached [6]. The test chimney shall be capable of maintaining a gas temperature at 1100 °F ±20 °F (593 °C ±11 °C) where the device assembly is inserted for testing. The test setup shall maintain a heat release rate of 300 000 ± 65 000 BTUs. The device to be tested shall not be exposed directly to flame.

Pressurize the assembly to 25% of the rated pressure of the device. Place the device into the chimney and record the time until the device activates.

Acceptable results: The device shall activate within 90 seconds.

6.8.1.6 Design and process Failure Mode and Effects Analysis (FMEA)

Design and process FMEA(s) shall be performed for device assemblies. Qualification FMEA reports shall be kept on file by the manufacturer and made available to the authorities having jurisdiction upon request. Available references include SAE J1739, *Potential Failure Mode and Effects Analysis in Design (Design FMEA) and Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA)*, and FMEA *Potential Failure Mode and Effects Analysis* [12, 13].

6.8.1.7 Structural burst test

For devices that do not have a piping interface on the exit of the device, the pressure relief mechanism is to be rendered inoperable and it is to be pressurized until failure. For devices that do have a piping interface on the exit of the device, the device is to be fully activated and with the exit blocked, the device is to be pressurized until failure. The failure pressure shall be at or above four times the device's maximum rated pressure.

6.8.1.8 Pressure cycle test

Five units of the pressure relief device assembly shall be cycled (1000 x design life [DL]) times between not more than 10% and not less than 125% of the maximum rated pressure. The first 10% of the test cycles shall be conducted at a temperature of 180 °F (82 °C). The remaining cycles shall be conducted at 135 °F (57 °C). The maximum pressure cycling rate is 10 cycles per minute.

After the cycling test, the pressure relief device shall meet the requirements of 6.8.1.5 and 6.8.2.1

6.8.1.9 Accelerated life tests

Five pressure relief device assemblies shall be placed in an oven or liquid bath at a temperature determined by the formula below. The temperature of the device shall be held constant within ± 2 °F (± 1 °C) throughout the test. Each device shall be pressurized on the inlet of the device to 125% of the maximum rated service pressure and held constant within ± 2% of the test pressure. If a manifold system is used, a suitable method should be used to prevent pressure depletion of the system when one specimen fails.

All five assemblies shall meet 500 hours at the test temperature and pressure.

$$T_L = e\left[\ln\left(\frac{T_{ref}}{T_f}\right) * \left(1 - \frac{2.87 + \ln(DL)}{5.57 + \ln(DL)}\right) + \ln(T_f)\right]$$

Where:

T_{ref} = the reference temperature +135 °F (+57 °C)

T_f = the fusible material melt temperature, °F (°C) as determined by 6.1.1

T_L = the long-term test temperature

°F (°C) DL = the design service life in years

1 ≤ DL ≤ 20

Each sample assembly shall be subjected to the tests outlined in 6.8.1.5 and 6.8.2.1 and meet the acceptance criteria of those tests.

6.8.2 Production batch inspection

One batch of completed devices shall not use multiple batches of fusible material. The batch size of fusible materials shall be limited to what can be produced by one common heat of raw materials (e.g., a single oven melt) but shall not exceed 3000 units. The fusible material yield temperature shall be determined in accordance with 6.1.1. Batch sizes shall be consistent with good manufacturing practice and appropriate levels of inspection using the results of the FMEA performed in accordance with the requirements of 6.8.1.6.

Production inspections test shall use units selected at random. The tests shall be conducted on fusible materials, device components, and finished device assemblies.

When the test results fail to meet requirements, the relief device or component batch shall be rejected. Retest of a rejected batch is authorized if the equipment or procedure was faulty. One retest of a rejected batch is authorized if an improper test was made due to the presence of a defect in the specimen. A batch shall be 100% inspected to remove defective assemblies or components from the batch. A second sample shall then be selected from the batch and tested. The batch is considered acceptable if the second sample meets the batch criteria.

6.8.2.1 Leakage

Each pressure relief device assembly shall be pressurized to 125% of the rated pressure of the device. The pressure relief device assembly shall not leak gas at a rate greater than 8 scc/hr of helium.

7 Identification requirements

The purpose of this section is to list certain safeguards or guides so pressure relief device performance is not jeopardized by improper service practices. The aim is to make it possible to identify the manufacturer of the device and to have the main replaceable parts identified or coded so it is readily determined whether parts are intended to function together, what operating pressure range or temperature range they will provide for, and whether they have adequate flow capacity for the cylinder with which they are to be used. This can usually be determined by reference to manufacturer's published data.

CAUTION: *Rupture disks can be applied only against pressure openings for which they were specifically designed. Some manufacturers use sharp pressure-opening contours while others use rounded or other shaped contours. Because of these contour variations, an interchange of the disks will give widely different burst pressures. In addition, variation in diameter for the pressure opening will give still wider variation in burst pressure if the disks are interchanged improperly.*

7.1

Suitable marking shall be provided to identify the manufacturer of the pressure relief device.

7.2

When rupture disks and pressure opening parts are designed to be replaced as individual parts, they shall be marked to indicate the rated burst pressure (when used in conjunction with the proper mating part), the flow capacity, and the manufacturer. Suggested methods of marking are as follows:

- Stamp with manufacturer's name or trademark and rated burst pressure or identifying part number on the part containing the pressure opening;
- Ink or otherwise mark the number on the rupture disk or apply some other code mark to facilitate determination of burst pressure range and the proper mating part; and
- When rupture disk and pressure opening parts are combined in a factory assembled pressure relief device designed to be replaced as a unit (CG-1, CG-4, or CG-5), the assembly shall be externally marked to indicate the rated burst pressure, flow capacity, manufacturer, and yield temperature if applicable.

7.3

Fusible plug devices shall be marked to be visible after installation to indicate their operating characteristics and manufacturer.

7.3.1 CG-2 and CG-3 devices

CG-2 and CG-3 devices shall be marked to indicate yield temperature.

7.3.2 CG-9 devices

CG-9 devices shall be marked 217 °F (102.7 °C) and CG-9. In addition, CG-9 devices shall be marked to clearly indicate the maximum cylinder service pressures for which the devices can be used.

7.4

Pressure relief valves shall be marked to indicate:

- the manufacturer;
- the set pressure for which the valve is set to start-to-discharge;
- the flow rating pressure in psig at which the flow capacity of the valve is determined; and
- the flow capacity in ft^3 per minute of free air.

7.5 CG-8 devices

The rupture disk portion of the CG-8 device shall be marked in accordance with the requirements of 7.2 except that the area of the minimum orifice of the system shall be marked instead of the flow capacity.

The pressure relief valve portion of the CG-8 device shall be marked in accordance with the requirements of 7.4. The manufacturer's flow capacity in ft^3 per minute of free air shall be the capacity of the relief valve portion of the CG-8 device only.

7.6

All markings required in 7.2 through 7.5 may be coded except for CG-9 devices where coding is not permitted. Coding designations shall be determinable from the manufacturer. Pressure relief devices used on DOT-39 and TC-39M cylinders are exempt from marking requirements.

7.7 CG-10 devices

CG-10 relief devices shall be marked with:

- CG-10;
- manufacturer's identification;
- part number;
- batch number or date of manufacture;
- rated service pressure range; and
- remove-from-service date.

Markings shall be permanent. Permanent adhesive labels are permissible or markings may be etched or stamped into the device housing.

8 Maintenance requirements for pressure relief devices

8.1 General practices

8.1.1 Cylinder and pressure relief device care

As a precaution to keep cylinder pressure relief devices in reliable operating condition, care shall be taken in the handling or storage of compressed gas cylinders to avoid damage. Care shall also be exercised to avoid plugging of pressure relief device channels and parts by paint or other foreign matter, which could interfere with the functioning of the device. Only trained personnel shall be allowed to service pressure relief devices. Only assemblies or original manufacturer's parts shall be used in the repair of pressure relief devices unless the interchange of parts has been proven by suitable test.

8.1.2 Industrial motor fuel applications

For all industrial motor fuel applications, cylinder pressure relief devices or their discharge outlet piping shall be equipped with a device to prevent plugging of the external relief device channel. Any such device shall not adversely restrict the operating pressure or flow rating of the pressure relief device.

8.1.3 Repaired or reconditioned pressure relief devices

New pressure relief devices that are found to be in noncompliance with Section 6 of this standard may be repaired by the manufacturer provided they are retested as required to confirm that they satisfy the requirements of this standard.

CG-2, CG-3, CG-7, CG-8 (the pressure relief valve portion), CG-9, and CG-10 devices shall not be reconditioned except for external cleaning. No attempt should be made to replace or refill the fusible metal in devices that have been in service. No attempt should be made to replace parts in or adjust the pressure setting on CG-7 devices once the manufacturer has set them.

8.2 Routine checks when filling cylinders

Each time a compressed gas cylinder is received for refilling, all pressure relief devices shall be examined externally for corrosion, damage, rust, presence of a protective device as specified in 8.1.2, plugging of external pressure relief device channels, and mechanical defects such as leakage or extrusion of fusible metal. This examination does not apply to CTC/DOT-4L or TC-4LM cylinders. If there is any doubt regarding the suitability of the pressure relief device for service, the cylinder shall not be filled until it is equipped with a suitable device.

9 Periodic replacement of pressure relief devices

9.1 CG-7 pressure relief valve

9.1.1

Cylinders shall not be charged and shipped if the relief device requirements of 9.1.1.1 and 9.1.1.2 are not fulfilled.

9.1.1.1

All pressure relief valves (CG-7), other than those in industrial motor fuel service, shall be replaced or requalified within 10 years after the date of manufacture of the relief valve. CG-7 devices designed for requalification may be requalified. Requalification shall be in accordance with Appendix B. Requalified valves shall be retested on a 5-year frequency. Requalified valves shall be permanently marked to identify the particular valve, requalification date, and retester. The retester shall certify the requalified valves meet the requirements of Appendix B. Further, the retester shall maintain records of the most recent test for a minimum of 6 years from the requalification date of the valve.

9.1.1.2

All pressure relief valves (CG-7) in industrial motor fuel service shall be replaced with a new or unused valve within 10 years after the date of manufacture of the relief valve or within the requalification period of the cylinder on which they are installed. Requalification of these pressure relief valves is not permitted.

9.1.1.3

The pressure relief valve portion of a CG-8 system shall be replaced or requalified in accordance with the requirements of 9.1.1.

10 References

Unless otherwise specified, the latest edition shall apply.

[1] *Code of Federal Regulations*, Title 49 CFR Parts 100-180 (Transportation), Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. www.access.gpo.gov

[2] *Transportation of Dangerous Goods Regulations*, Transport Canada, Canadian Government Publishing, Public Works and Government Services Canada, Ottawa, ON K1A 0S9, Canada. www.tc.gc.ca

[3] CGA S-1.2, *Pressure Relief Device Standards—Part 2—Cargo and Portable Tanks for Compressed Gases*. Compressed Gas Association, Inc., 4221 Walney Rd., 5th Floor, Chantilly, VA 20151. www.cganet.com

[4] CGA S-1.3, *Pressure Relief Device Standards—Part 3—Stationary Storage Containers for Compressed Gases*, Compressed Gas Association, Inc., 4221 Walney Rd., 5th Floor, Chantilly, VA 20151. www.cganet.com

[5] CGA P-11, *Metric Practice Guide for the Compressed Gas Industry*, Compressed Gas Association, Inc., 4221 Walney Rd., 5th Floor, Chantilly, VA 20151. www.cganet.com

[6] CGA C-14, *Procedures for Fire Testing of DOT Cylinder Pressure Relief Device Systems*, Compressed Gas Association, Inc., 4221 Walney Rd., 5th Floor, Chantilly, VA 20151. www.cganet.com

[7] Gas Measurement Committee Report No. 3, *Orifice Metering of Natural Gas*, American Gas Association, 400 N. Capitol St., NW, Washington, DC 20001. (Reprinted with revisions 1969) www.aga.org

[8] ANSI/ASME PTC 25, *Performance Test Code—Pressure Relief Devices*, ASME International, Three Park Ave., New York, NY 10016. www.asme.org

[9] CGA C-12, *Qualification Procedure for Acetylene Cylinder Design*. Compressed Gas Association, Inc., 4221 Walney Rd., 5th Floor, Chantilly, VA 20151. www.cganet.com

[10] The Chlorine Institute Pamphlet No. 17, *Packaging Plant Safety and Operational Guidelines–Revision 1*, The Chlorine Institute, Inc., 1300 Wilson Blvd., Rosslyn, VA 22209. www.cl2.com

[11] ASTM B117-02, *Standard Practice for Operating Salt Spray (Fog) Apparatus*, ASTM International, 100 Barr Harbor Dr., West Conshohocken, PA 19428. www.astm.org

[12] SAE J1739, *Potential Failure Mode and Effects Analysis in Design (Design FMEA) and Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (Process FMEA) and Effects Analysis for Machinery (Machinery FMEA)*, Society of Automotive Engineers, 400 Commonwealth Dr., Warrendale, PA 15096. www.sae.org

[13] FMEA-3, *Potential Failure Mode and Effects Analysis*" FMEA, Automotive Industry Action Group, 26200 Lahser Rd., Suite 200, Southfield, MI 48034. www.aiag.org

[14] *How to Size Safety Relief Devices*, F. J. Heller, Phillips Petroleum Company, 1954.

11 Additional references

CGA V-1, *Compressed Gas Association Standard for Compressed Gas Cylinder Valve Outlet and Inlet Connections*, Compressed Gas Association, Inc., 4221 Walney Rd., 5th Floor, Chantilly, VA 20151. www.cganet.com

NFPA 58, *Liquefied Petroleum Gas Code*, National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269. www.nfpa.org

ASME Boiler and Pressure Vessel Code, (Section VIII, Division 1, Pressure Vessels), ASME International, Three Park Avenue, New York, NY 10016. www.asme.org

CAN/CSA B339, *Cylinders, Spheres, and Tubes for the Transportation of Dangerous Goods*, Canadian Standards Association, 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada. www.csa.ca

CAN/CSA B340, *Selection and Use of Cylinders, Spheres, Tubes, and Other Containers for the Transportation of Dangerous Goods— Class 2*, Canadian Standards Association, 5060 Spectrum Way, Mississauga, ON L4W 5N6, Canada. www.csa.ca

Introduction to Tables

Required pressure relief devices

The types of pressure relief devices listed in Table 1 are acceptable as indicated in Table 3 by a letter symbol or symbols for application on cylinders for various compressed gases and gas mixtures.

If a fire test is required, it shall be performed in accordance with CGA C-14 and CGA C-12 [5, 8]. A fire test shall be conducted when the flow capacity of a pressure relief device is sized less than required by formula in this standard.

Requests for types and applications of pressure relief devices other than those listed in Table 1 or Table 3 shall be sent to CGA for assignment and be accompanied by test data as shown on a form as suggested in Appendix A.

Table 1—Types of pressure relief devices

CG-1	Rupture disk
CG-2	165 °F (73.9 °C) Fusible plug for cylinder product pressure not exceeding 500 psig (3450 kPa)
CG-3	212 °F (100 °C) Fusible plug for cylinder product pressure not exceeding 500 psig (3450 kPa)
CG-4	Rupture disk with 165 °F (73.9 °C) fusible alloy backing
CG-5	Rupture disk with 212 °F (100 °C) fusible alloy backing
CG-7	Pressure relief valve
CG-8	Rupture disk followed by (in series) pressure relief valve
CG-9	217 °F (102.7 °C) Fusible plug for cylinder marked service pressures not exceeding 6000 psig (41 400 kPa)
CG-10	Fusible trigger device for cylinder marked service pressure on the device not exceeding 6000 psig (41 400 kPa)

Table 2—FTSC numerical code for gas classification

1st Digit — FIRE POTENTIAL

0	= inert
1	= supports combustion (oxidizing)
2	= flammable in air at 68 °F (20 °C) and 1 atmosphere.
3	= pyrophoric
4	= highly oxidizing
5	= may decompose or polymerize and is flammable

2nd Digit — TOXICITY

0	= life supporting (oxygen ≥ 19.5% in simple asphyxiant)
1	= LC_{50} > 5000 ppm
2	= 200 ppm < LC_{50} ≤ 5000 ppm
3	= LC_{50} ≤ 200 ppm

3rd Digit — STATE OF GAS: (in the cylinder at 70° F (21° C)[1])

0	= noncryogenic liquefied gas (less than 500 psi) (3450 kPa)[2]—gas withdrawal
1	= noncryogenic liquefied gas (over 500 psi) (3450 kPa)—gas withdrawal
2	= liquefied gas (liquid withdrawal)[3]
3	= dissolved/absorbed gas
4	= nonliquefied gas—or cryogenic gas withdrawal (less than 500 psi) (3450 kPa)
5	= Europe only
6	= nonliquefied gas between 500 psi and 3000 psi (3450 kPa and 20 680 kPa)
7	= nonliquefied gas above 3001 psi and below 10 000 psi (20 690 kPa and 68 950 kPa)
8	= cryogenic gas (liquid withdrawal) above –400 °F(–240°C)
9	= cryogenic gas (liquid withdrawal) below –400 °F (–240°C)

4th Digit — CORROSIVENESS:

0	= noncorrosive
1	= nonhalogen acid forming
2	= basic
3	= halogen acid forming

1) The temperature of the cryogenic gases is always below –130 °F (–90 °C).

2) If pressure at 130°F (54°C) is over 600 psi (4140 kPa), use digit 1.

3) When separate outlet for liquid withdrawal is specified.

Table 3—Alphabetical list of gases and devices assigned (see notes)

Note 1: When more than one type of device is listed in Table 3 for a particular gas, only one type is required.

Note 2: The symbols used in Table 3 are defined at the end of the table. Interpretation of these symbols is necessary to determine the type of relief device to be used with the specific lading.

Note 3: Type CG-4 and type CG-5 devices are not acceptable for 110% fill; see 49 CFR 173.302(c).

Note 4: For certain gases, use of pressure relief devices is not permitted. For such gases, the pressure relief device column is marked "Prohibited"; see 49 CFR 173.40.

Note 5: "None required" does not remove the possibility that a pressure relief device may be used.

Note 6: When used in direct medical service, CG-1 devices for carbon dioxide, carbon dioxide/nitrous oxide mixture (liquid), cyclopropane, and nitrous oxide shall be of the projecting type.

Note 7: The statement, "device is required in only one end" does not preclude use of a second device at the other end of the cylinder or tube.

CRYOGENIC LIQUIDS

FTSC Code	Gas	CG-1 Disk	CG-2 165 °F	CG-3 212 °F	CG-4 165 °F w/Disk	CG-5 212 °F w/Disk	CG-7 RV	CG-8 Disk/RV	CG-9 217 °F	CG-10
0180	Argon	G								
0190	Helium	G								
2190	Hydrogen	G								
0180	Neon	G								
0180	Nitrogen	G								
4080	Oxygen	G								

GASES

FTSC Code	LC_{50} PPM	Gas	CG-1 Disk	CG-2 165 °F	CG-3 212 °F	CG-4 165 °F w/Disk	CG-5 212 °F w/Disk	CG-7 RV	CG-8 Disk/RV	CG-9 217 °F	CG-10
5130		Acetylene			F						
2200		Acrylonitrile	NONE REQUIRED								
1060		Air	A		K B	B	B	K			B
2100		Allene		M				A			
		Allylene (See Methylacetylene)									
2102	7 338	Ammonia, Anhydrous (over 165lb) (None required if under 165lb)		E		Y					
0303	30	Antimony Pentafluoride	PROHIBITED								
0160		Argon	A			B	B	K			B
2300	20	Arsine	PROHIBITED								
0303	20	Arsenic Pentafluoride	PROHIBITED								
		Boron Chloride (See Boron Trichloride)									
		Boron Fluoride (See Boron Trifluoride)									
0203	2 541	*Boron Trichloride		L		B C					
0263	806	Boron Trifluoride				T	T				
4303	50	*Bromine Pentafluoride	PROHIBITED								
4303	180	*Bromine Trifluoride	PROHIBITED								
0203	260	*Bromoacetone				T					
0100		*Bromochlorodifluoromethane (R12B1) or (Halon1211)	L					L			

FTSC Code	LC_{50} PPM	Gas	CG-1 Disk	CG-2 165 °F	CG-3 212 °F	CG-4 165 °F w/Disk	CG-5 212 °F w/Disk	CG-7 RV	CG-8 Disk/RV	CG-9 217 °F	CG-10
0100		*Bromochloromethane (Halon1011)	NONE REQUIRED								
0100		Bromodifluoromethane (HBFC-22 B1)	A					A			
		Bromoethylene (See Vinyl Bromide)									
		Bromomethane (See Methyl Bromide)									
3100		Bromotrifluoroethylene (R113B1)	C					A			
0100		Bromotrifluoromethane (R13B1 or Halon 1301)	A					A			
5100	220 000	1,3 Butadiene, (Inhibited)						A			
2100		Butane, Normal			M			A			
2100		1-Butene						A			
2100		2-Butene						A			
0110		Carbon Dioxide	A			S		K		W	
		Carbon Dioxide/Nitrous Oxide Mixture (Liquid)	A			S					
		Carbon Dioxide/Oxygen Mixture (Gas)	A			B	B	K			
2200		Carbon Disulfide	NONE REQUIRED								
		Carbonic Acid (See Carbon Dioxide)									
2260	3 760	Carbon Monoxide				J	J				
		Carbon Oxysulfide (See Carbonyl Sulfide)									
		Carbon Tetrachloride (See Tetrachloromethane)									
		Carbon Tetrafluoride (See Tetrafluoromethane)									
		Carbonyl Chloride (See Phosgene)									
0213	360	Carbonyl Fluoride				T					
2201	1 700	Carbonyl Sulfide		B		BC					
4203	293	Chlorine (see 6.2.4)		H I		C Z I					
4303	122	Chlorine Pentafluoride	PROHIBITED								
4203	299	Chlorine Trifluoride				T					
2100		Chlorodifluoroethane (R142b)		M	M			A			
0100		Chlorodifluoromethane (R22)	A	M	M			A			
0100		Chlorodifluoromethane/ Chloropentafluoroethane (Mixture) (R502)	A	M	M			A			
		Chloroethane (See Ethyl Chloride)									
		Chloroethylene (See Vinyl Chloride)									
2100		Chlorofluoromethane (R31)						A			
0100		Chloroheptafluorocyclobutane (RC317)	A					A			
		Chloromethane (See Methyl Chloride)									
0100		Chloropentafluoroethane (R115)	A					A			
0100		1-Chloro-1,2,2,2-Tetrafluoroethane (R124)	A					A			
0100		1-Chloro-2,2,2-Trifluoroethane (R133a)	A					A			
5200	2 000	Chlorotrifluoroethylene (R1113)	C					A			
0100		Chlorotrifluoromethane (R13)	A			P					
2200	350	Cyanogen				T					
0303	80	Cyanogen Chloride	PROHIBITED								
2100		Cyclobutane		M				A			

FTSC Code	LC_{50} PPM	Gas	CG-1 Disk	CG-2 165 °F	CG-3 212 °F	CG-4 165 °F w/Disk	CG-5 212 °F w/Disk	CG-7 RV	CG-8 Disk/RV	CG-9 217 °F	CG-10
2100	220 000	Cyclopropane	A	M		S		A			
2160		Deuterium	N			J	J				
0213	3 120	Deuterium Chloride				B					
0203	1 100	*Deuterium Fluoride	NONE REQUIRED								
2301	2	Deuterium Selenide	PROHIBITED								
2201	710	Deuterium Sulfide		B		BC					
5360	80	Diborane	PROHIBITED								
1100	27 000	*Dibromodifluoroethane	NONE REQUIRED								
0100		*Dibromodifluoromethane (R12B2) (Halon1202)	NONE REQUIRED								
		Dibromomethane (See Methylene Bromide)									
0100		*1,2 Dibromotetrafluoroethane (R114B2) (Halon 2402)	L					L			
0100		*1,2 Dichlorodifluoroethylene	NONE REQUIRED								
0100		Dichlorodifluoromethane (R12)	A	M	M			A			
0100		Dichlorodifluoromethane/Difluoroethane Mixture (R500)	A	M	M			A			
0200		*1,2 Dichloroethylene (R1130)	NONE REQUIRED								
0100		*Dichlorofluoroemethane (R21)	L					L			
0100		*1,2 Dichlorohexafluorocyclobutane (RC316)	NONE REQUIRED								
2100		Dichloromethane	NONE REQUIRED								
2203	314	*Dichlorosilane				T					
0100		*1,1 Dichlorotetrafluoroethane (R114a)	L	M	M			L			
0100		*Dichlorotetrafluoroethane (R114)	L	M	M			L			
0100		*2,2 Dichloro-1,1,1-Trifluoroethane (R123)	NONE REQUIRED								
		Dicyan (See Cyanogen)									
3300	10	*Diethylzinc	PROHIBITED								
2100		1,1 Difluoroethane (R152a)		M	M			A			
2110		1,1 Difluoroethylene (R1132a)	A			B					
		Difluoromethane (See Methylene Fluoride)									
2102		*Dimethylamine, Anhydrous	NONE REQUIRED								
		Dimethyl Disulfide (See Methyl Disulfide)									
2100		Dimethyl Ether						A			
2100	>5 000	*Dimethylsilane	NONE REQUIRED								
		Dimethyl Sulfide (See Methyl Sulfide)									
2100		*2,2 Dimethylpropane						L			
0303	2	Diphosgene	PROHIBITED								
2110		Ethane	J								
		Ethanethiol (See Ethyl Mercaptan)									
2100		*Ethylacetylene		L				L			
2100		*Ethyl Chloride		L				L			
0303	36	Ethyldichloroarsine	PROHIBITED								
2160		Ethylene	J								
5200	2 920	*Ethylene Oxide	SEE 49 CFR 173.323								

FTSC Code	LC_{50} PPM	Gas	CG-1 Disk	CG-2 165 °F	CG-3 212 °F	CG-4 165 °F w/Disk	CG-5 212 °F w/Disk	CG-7 RV	CG-8 Disk/RV	CG-9 217 °F	CG-10
2100		*Ethyl Ether						L			
2100		Ethyl Fluoride				T					
2100		Ethyl Mercaptan	NONE REQUIRED								
4343	185	Fluorine	PROHIBITED								
		Fluoroform (R23) (See Trifluoromethane)									
2200	622	Germane				T					
0203		Germanium Tetrafluoride	PROHIBITED								
0160		Helium	A			B	B	K			B
		Helium/Oxygen Mixture	A			B	B	K			
2300	10	Heptafluorobutyronitrile	PROHIBITED								
0100		Heptafluoropropane (HFC-227 ea)	A					A			
0203	470	Hexafluoroacetone		I		I					
2100	>5 000	Hexafluorocyclobutene				T					
0100		Hexafluoroethane (R116)	A			B					
0100		Hexafluoropropylene (R1216)	A					A			
2160		Hydrogen	N			J	J	K			J
2130		Hydrogen absorbed in metal hydride									
0203	2 860	Hydrogen Bromide				B					
0213	3 120	Hydrogen Chloride				B			Q		
5301	140	Hydrogen Cyanide	PROHIBITED								
0203	1 276	*Hydrogen Fluoride	NONE REQUIRED								
0203	2 860	Hydrogen Iodide				B					
2301	2	Hydrogen Selenide	PROHIBITED								
2201	712	Hydrogen Sulfide		I		I					
4303	120	*Iodine Pentafluoride	PROHIBITED								
0203		Iodomethane	NONE REQUIRED								
2100		Isobutane						A			
2100		Isobutylene						A			
0160		Krypton	A			B	B	K			B
0303		Lewisite (Dichloro 2-Chloro Vinyl Arsine)	PROHIBITED								
2160		Methane	N			J	J	K			J
2100		Methylacetylene		M				A			
0200	850	*Methyl Bromide	NONE REQUIRED								
2100		*3-Methyl-1-Butene						L			
2100		Methyl Chloride						A			
0303		Methyldichloroarsine	PROHIBITED								
2300		Methyl Disulfide	NONE REQUIRED								
2203		*Methylene Bromide	NONE REQUIRED								
2110		Methyl Fluoride				B					
		Methylene Chloride (See Dichloromethane)									
2110		Methylene Fluoride (R32)	A					A			
2100		*Methyl Formate	NONE REQUIRED								
0303		*Methyl Iodide	NONE REQUIRED								
2201	1 350	Methyl Mercaptan	NONE REQUIRED								

FTSC Code	LC_{50} PPM	Gas	CG-1 Disk	CG-2 165 °F	CG-3 212 °F	CG-4 165 °F w/Disk	CG-5 212 °F w/Disk	CG-7 RV	CG-8 Disk/RV	CG-9 217 °F	CG-10
2100		Methylsilane				B					
2100		Methyl Sulfide	NONE REQUIRED								
2102		*Monoethylamine	NONE REQUIRED								
2102		Monomethylamine, Anhydrous	NONE REQUIRED								
0303	4	Mustard Gas	PROHIBITED								
2160		Natural Gas	N			J	J	K		X	J
0160		Neon	A			B	B	K			B
2300	20	*Nickel Carbonyl	PROHIBITED								
4361	115	Nitric Oxide	PROHIBITED								
0160		Nitrogen	A		KB	B	B	K			B
4301	115	*Nitrogen Dioxide	PROHIBITED								
4301		*Nitrogen Tetroxide	PROHIBITED								
4160	6 700	Nitrogen Trifluoride			T	T	T				
4301	115	Nitrogen Trioxide	PROHIBITED								
0303	115	Nitrosyl Chloride	NONE REQUIRED -10LB WEIGHT AND UNDER								
0303	35	Nitrosyl Fluoride	PROHIBITED								
4110		Nitrous Oxide	A			S					
0303		Nitryl Fluoride	PROHIBITED								
0100		Octafluorocyclobutane (RC318)	A					A			
0200		*Octafluorocyclopentene (C5F8)	NONE REQUIRED								
0100		Octafluoropropane (R218)	A					A			
4060		Oxygen	A			B	B	K			
4343	2.6	Oxygen Difluoride	PROHIBITED								
4330		Ozone (Dissolved in R13)	PROHIBITED								
3300	10	*Pentaborane	PROHIBITED								
0100		Pentafluoroethane (HFC-125)	A	M	M			A			
2300	10	Pentafluoropropionitrile	PROHIBITED								
4203	770	Perchloryl Fluoride				T					
2200		Perfluorobutadiene				B					
0100		*Perfluorobutane (FC-3-1-10)		L				L			
0100	12 000	*Perfluoro-2-Butene		L							
0303	5	Phenylcarbylamine Chloride	PROHIBITED								
0303	5	Phosgene	PROHIBITED								
3310	20	Phosphine	PROHIBITED								
0303	255	Phosphorous Pentafluoride				T					
0203	425	Phosphorous Trifluoride				B					
2100		Propane			M			A			
2100		Propylene						A			
3160	19 000	Silane				D					
0203	750	*Silicon Tetrachloride	NONE REQUIRED								
0263	450	Silicon Tetrafluoride				T	T				
5300	20	Stibine	PROHIBITED								
0201	2 520	Sulfur Dioxide		B							
0100		Sulfur Hexafluoride	A			B	B	A			

FTSC Code	LC_{50} PPM	Gas	CG-1 Disk	CG-2 165 °F	CG-3 212 °F	CG-4 165 °F w/Disk	CG-5 212 °F w/Disk	CG-7 RV	CG-8 Disk/RV	CG-9 217 °F	CG-10
0303	40	Sulfur Tetrafluoride	PROHIBITED								
0200	3 020	Sulfuryl Fluoride		B							
0100		Tetrachloromethane	NONE REQUIRED								
0100		1,1,1,2 Tetrafluoroethane (R-134a)	A	M	M			A			
<u>5100</u>		Tetrafluoroethylene-Inhibited (R1114)	A			B					
4340	100	Tetrafluorohydrazine	PROHIBITED								
0160		Tetrafluoromethane (R-14)	A			B	B	K			
2200		*Tetramethyllead				T					
0100		*Trichlorofluoromethane (R11)	NONE REQUIRED								
0100		Trichloroethylene	NONE REQUIRED								
2203	1 040	*Trichlorosilane	NONE REQUIRED								
0100		*1,1,1 Trichlorotrifluoroethane (R113a)	NONE REQUIRED								
0100		*1,1,2 Trichlorotrifluoroethane (R113)	NONE REQUIRED								
3300	10	Triethylaluminum	PROHIBITED								
3200	1 400	Triethylborane				T					
2200	500	Trifluoroacetonitrile				T					
0203	208	Trifluoroacetylchloride	PROHIBITED								
2100		1,1,1 Trifluoroethane (R143a)		M				A			
0110		Trifluoromethane (HFC-23)	A			B					
4363		Trifluoromethyl Hypofluorite	PROHIBITED								
0200		Trifluoromethyl Iodide				B					
2102	7 000	*Trimethylamine	NONE REQUIRED								
<u>2100</u>	>5 000	*Trimethylsilane	NONE REQUIRED								
3300	20	Trimethylstibine	PROHIBITED								
0203	213	*Tungsten Hexafluoride	NONE REQUIRED								
0303		*Uranium Hexafluoride	PROHIBITED								
5100	>5 000	*Vinyl Bromide		L				L			
5100	>5 000	Vinyl Chloride		E				A			
<u>5100</u>	>5 000	Vinyl Fluoride				B					
5100	>5 000	Vinyl Methyl Ether		E				A			
0160		Xenon	A			B		K			B

*Not a compressed gas.

Definitions of symbols used in Table 3

A. This device is required <u>in only one end of the cylinder or tube regardless of length (see note 7).</u>

B. When cylinders are over 65 in (1651 mm) long exclusive of the neck, this device is required at both ends. For shorter cylinders, the device is required in one end only.

C. This device is permitted only in cylinders having a minimum required test pressure of 3000 psig (20 680 kPa) or higher and is required in one end only. The bursting pressure of the disk shall be at least 75% of the minimum required test pressure of the cylinder.

D. For tubes, this device is required at both ends. For cylinders with nominal water capacity more than 50 liters and/or with fill pressure above 1250 psig at 70 °F (fill density of 0.274 gms/cc), the device is required only at one end. <u>When the devices are used at both ends of a cylinder or tube, the flow capacity of each device may be combined to meet the minimum flow capacity requirement. In no case shall the flow capacity at one end of</u>

the tube be less than 50% of the minimum flow capacity requirement. For cylinders with nominal water capacity of 50 liters or less and with fill pressure below 1250 psig at 70 °F (fill density of 0.274 gms/cc), the use of this device is not required.

E. When cylinders are over 30 in (762 mm) long exclusive of the neck, this device, when used, is required at both ends. For shorter cylinders, the device, when used, is required in one end only.

F. The number and location of pressure relief devices for cylinders of any particular size shall be proved adequate as a result of the fire test. Any change in style of cylinder, a filler, or quantity of devices can only be approved if found adequate upon reapplication of the fire test. The fire test shall be conducted in accordance with CGA C-12 [9].

G. This device is required in one end of the cylinder only, regardless of length. A pressure controlling valve as required in 49 CFR 173.316(b) shall also be used [1]. This valve shall be both sized and set so as to limit the pressure in the cylinder to 1-1/4 times its marked service pressure less 15 psi (103 kPa) if vacuum insulation is used. The insulation jacket shall be provided with a pressure-actuated device that will function at a pressure of not more than 25 psig (172 kPa) and provide a minimum discharge area of 0.00012 in^2 per lb (0.171 mm^2 per kg) water capacity of cylinder.

An alternate pressure relief valve with a marked set pressure not to exceed 150% of the DOT service pressure may be used in lieu of the rupture disk device if the flow capacity required for relief devices on CTC/DOT 4L and TC-4LM specification insulated cylinders is provided at 120% of marked set pressure. Installation shall provide for:

- prevention of moisture accumulation at the seat by drainage away from that area;
- periodic drainage of the vent piping; and
- avoidance of foreign material in the vent piping.

H. When cylinders are over 55 in (1397 mm) long exclusive of the neck, this device is required in both ends except for cylinders purchased after October 1, 1944 that shall contain no aperture other than that provided in the neck of the cylinder for attachment of a valve equipped with an approved pressure relief device. Chlorine cylinders do not generally exceed 55 in (1397 mm) in length since 49 CFR 173.301(a)(2) Note 2 of DOT regulations requires that cylinders purchased after November 1, 1935 shall not contain over 150 lb (68 kg) of chlorine [1].

J. This device is required in only one end of cylinders having a length not exceeding 65 in (1651 mm) exclusive of the neck. For cylinders over 65 in (1651 mm) long, this device is required in both ends, and each device shall be arranged to discharge upwards and unobstructed to the open air in such a manner as to prevent any impingement of escaping gas upon the containers.

K. This device can be used up to 500 psig (3450 kPa) charging pressure.

L. This device is recommended, but no pressure relief device is required by 49 CFR [1].

M. May be used in conjunction with CG-7 (see 4.3.1).

N. This device is required in only one end of tubes. The device shall be arranged to discharge upwards and unobstructed to the open air in such a manner as to prevent any impingement of escaping gas upon the containers (see note 7).

P. For use only on cylinders over 65 in (1651 mm) long. This device is required on both ends.

Q. It is permissible to install a CG-8 device in addition (parallel) to the CG-4 device. It is permitted only at one end of the cylinder regardless of length.

R. This fusible plug device may be used at pressures up to the maximum service pressure of the cylinder for which the device's use is intended but no more than 6000 psig (41 400 kPa). When cylinders are over 65 in (1651 mm) long exclusive of the neck, this device is required at both ends. For shorter cylinders, the device is required in one end only.

S. No longer authorized for refilling. CG-1 projection-type relief device shall be used.

T. No pressure relief device required. This device is to be selected if a pressure relief device is used.

W. May be used in parallel with CG-1 (see 4.1.5).

X. May be used in parallel with a CG-7 device (see 4.1.5) at pressures up to the maximum service pressure of the cylinder for which the device's use is intended, but no more than 3600 psig (24 820 kPa).

Y. This device is permitted only in cylinders with a capacity of 1000 lb or less. When cylinders are over 65 in (1651 mm) long exclusive of the neck, this device is required at both ends. For shorter cylinders, this device is permitted in cylinders having a minimum required test pressure of 3000 psig (20 680 kPa) or higher and is required in one end only. The bursting pressure of the disk shall be at least 75% of the minimum required test pressure of the cylinder.

Z. Cylinders over 55 in (1397 mm) long exclusive of the neck are not permitted to use the CG-4 pressure relief device. Also, cylinders manufactured prior to October 1, 1944 are not permitted to be equipped with the CG-4 pressure relief device.

Table 4—Temperature correction factors to 60 °F

Degrees F	Factor	Degrees F	Factor	Degrees F	Factor
1	1.0621	51	1.0088	101	0.9628
2	1.0609	52	1.0078	102	0.9619
3	1.0598	53	1.0068	103	0.9610
4	1.0586	54	1.0058	104	0.9602
5	1.0575	55	1.0048	105	0.9594
6	1.0564	56	1.0039	106	0.9585
7	1.0552	57	1.0029	107	0.9577
8	1.0541	58	1.0019	108	0.9568
9	1.0530	59	1.0010	109	0.9560
10	1.0518	60	1.0000	110	0.9551
11	1.0507	61	0.9990	111	0.9543
12	1.0496	62	0.9981	112	0.9535
13	1.0485	63	0.9971	113	0.9526
14	1.0474	64	0.9962	114	0.9518
15	1.0463	65	0.9952	115	0.9510
16	1.0452	66	0.9943	116	0.9501
17	1.0441	67	0.9933	117	0.9493
18	1.0430	68	0.9924	118	0.9485
19	1.0419	69	0.9915	119	0.9477
20	1.0408	70	0.9905	120	0.9469
21	1.0398	71	0.9896	121	0.9460
22	1.0387	72	0.9887	122	0.9452
23	1.0376	73	0.9877	123	0.9444
24	1.0365	74	0.9868	124	0.9436
25	1.0355	75	0.9859	125	0.9428
26	1.0344	76	0.9850	126	0.9420
27	1.0333	77	0.9840	127	0.9412
28	1.0323	78	0.9831	128	0.9404
29	1.0312	79	0.9822	129	0.9396
30	1.0302	80	0.9813	130	0.9388
31	1.0291	81	0.9804	131	0.9380
32	1.0281	82	0.9795	132	0.9372
33	1.0270	83	0.9786	133	0.9364
34	1.0260	84	0.9777	134	0.9356
35	1.0249	85	0.9768	135	0.9349
36	1.0239	86	0.9759	136	0.9341
37	1.0229	87	0.9750	137	0.9333
38	1.0218	88	0.9741	138	0.9325
39	1.0208	89	0.9732	139	0.9317
40	1.0198	90	0.9723	140	0.9309
41	1.0188	91	0.9715	141	0.9302
42	1.0178	92	0.9706	142	0.9294
43	1.0168	93	0.9697	143	0.9286
44	1.0158	94	0.9688	144	0.9279
45	1.0147	95	0.9680	145	0.9271
46	1.0137	96	0.9671	146	0.9263
47	1.0127	97	0.9662	147	0.9256
48	1.0117	98	0.9653	148	0.9248
49	1.0108	99	0.9645	149	0.9240
50	1.0098	100	0.9636	150	0.9233

From AGA Gas Measurement Committee Report No. 3, *Orifice Metering of Natural Gas* [7].

Table 5—Basic orifice factors flange taps for flow in ft^3 per minute

Base temperature 60 °F Base pressure 14.696 psia				Flow temperature 60 °F Specific gravity 1.0	
Orifice diameter	**Pipe sizes—extra heavy, schedule 80** **Nominal and published inside diameters (in)**				
(In)	**2** **1.939**	**3** **2.900**	**4** **3.826**	**6** **5.761**	**8** **7.981**
0.250	0.2118	0.2118*	0.2115*		
0.375	0.4740	0.4730	0.4726*		
0.500	0.8431	0.8386	0.8372	0.8364*	
0.625	1.3252	1.3114	1.3075	1.3049	
0.750	1.9270	1.8950	1.8858	1.8792	
0.875	2.6593	2.5902	2.5733	2.5605	2.5552
1.000	3.5412	3.4007	3.3700	3.3493	3.3398
1.125	4.6033	4.3325	4.2782	4.2453	4.2315
1.250	5.8930	5.3938	5.3005	5.2492	5.2297
1.375	7.4762	6.5967	6.4408	6.3617	6.3343
1.500		7.9560	7.7045	7.5838	7.5463
1.625		9.4942	9.0982	8.9172	8.8658
1.750		11.2407	10.6310	10.363	10.293
1.875		13.2313	12.3130	11.924	11.830
2.000		15.5108	14.157	13.602	13.475
2.125		18.1876	16.183	15.401	15.231
2.250			18.412	17.325	17.098
2.375			20.868	19.377	19.078
2.500			23.588	21.563	21.172
2.625			26.583	23.892	23.382
2.750			29.952	26.368	25.708
2.875				29.000	28.155
3.000				31.797	30.725
3.125				34.773	33.420
3.250				37.942	36.243
3.375				41.318	39.200
3.500				44.918	42.295
3.625				48.762	45.530
3.750				52.868	48.913
3.875				57.262	52.448
4.000				61.970	56.142
4.250				72.580	64.038
4.500					72.675
4.750					82.135
5.000					92.530
5.250					103.940
5.500					116.533
5.750					130.500
6.000					

* These orifices have diameter ratios lower than the minimum value for which the formulas used were derived and this size of plate should not be used unless it is understood that the accuracy of measurement will be relatively low. (Data were taken from Gas Measurement Committee Report No.3, *Orifice Metering of Natural Gas* (1956 Reprint), American Gas Association, and converted to calculations in ft^3 per minute.) [7].

Table 6—Values of G_i and G_u for rated burst pressures of rupture disks for CTC/DOT-4L and TC-4LM cylinders

Commodity	Rated burst pressure or Flow rating pressure		Value of G_i		Value of G_u	
	Customary units (psig)	Metric (SI) units (kPa)	Customary units	Metric (SI) units	Customary units	Metric (SI) units
Argon, cryogenic liquid	100	690	10.2	5.95	59.0	704
	200	1380	11.8	6.88	69.0	823
	300	2070	13.8	8.05	82.0	978
	400	2760	17.9	10.44	108.0	1288
Helium, cryogenic liquid	200	1380	52.5	30.62		
Hydrogen, cryogenic liquid	50	345	8.6	5.02	45.8	546
	100	690	10.6	6.18	56.0	668
Neon, cryogenic liquid	100	690	17.0	9.92	92.0	1097
	200	1380	20.8	12.13	113.4	1352
	300	2070	28.0	16.33	153.0	1824
Nitrogen, cryogenic liquid	100	690	10.2	5.95	59.0	704
	200	1380	11.8	6.88	69.0	823
	300	2070	13.8	8.05	82.0	978
	400	2760	17.9	10.44	108.0	1288
Oxygen, cryogenic liquid	100	690	10.2	5.95	59.0	704
	200	1380	11.8	6.88	69.0	823
	300	2070	13.8	8.05	82.0	978
	400	2760	17.9	10.44	108.0	1288

NOTE—When lower rated burst pressures than those shown are used, the values of G_i and G_u are on the conservative side and may be used as shown or calculated as covered below. For higher rated burst pressures than shown, values of G_i and G_u shall be calculated from the following formulas in Table 6.

Table 6—Values of G_i and G_u for rated burst pressures of rupture disks for CTC/DOT-4L and TC-4LM cylinders (continued)

Customary units:

$$G_u = \frac{630\,000}{LC}\sqrt{\frac{Z\,(T+460)}{M}} \text{ and } G_i = \frac{73.4\,(1200 - T)}{LC}\sqrt{\frac{Z\,(T+460)}{M}}$$

Where:

L = Latent heat at flowing conditions in Btu per pound

C = Constant for gas or vapor related to ratio of specific heats ($k = C_p/C_v$) at 60 °F and 14.696 psia from Figure 1.

Z = Compressibility factor at flowing conditions

T = Temperature in °F (Fahrenheit) of gas at pressure at flowing conditions

M = Molecular weight of gas

Metric units:

$$G_u = \frac{23.58\,(10)^6}{LC}\sqrt{\frac{Z\,(T+273)}{M}} \text{ and } G_i = \frac{241\,(649 - T)}{LC}\sqrt{\frac{Z\,(T+273)}{M}}$$

Where:

L = Latent heat of gas at flowing conditions, kJ/kg

C = Constant for gas or vapor related to ratio of specific heats ($k = C_p/C_v$) at standard conditions, see Figure 1

Z = Compressibility factor at flowing conditions

T = Temperature in °C (Celsius) of gas at pressure at flowing conditions

M = Molecular weight of gas

When compressibility factor Z is not known, 1.0 is a conservative value to use for Z. When gas constant C is not known, 315 is a conservative value to use for C. For complete details concerning the basis and origin of these formulas, refer to *How to Size Safety Relief Devices*, F. J. Heller [14].

k	CONSTANT *C*	*k*	CONSTANT *C*	*k*	CONSTANT *C*
1.00	315	1.26	343	1.52	366
1.02	318	1.28	345	1.54	368
1.04	320	1.30	347	1.56	369
1.06	322	1.32	349	1.58	371
1.08	324	1.34	351	1.60	372
1.10	327	1.36	352	1.62	374
1.12	329	1.38	354	1.64	376
1.14	331	1.40	356	1.66	377
1.16	333	1.42	358	1.68	379
1.18	335	1.44	359	1.70	380
1.20	337	1.46	361	2.00	400
1.22	339	1.48	363	2.20	412
1.24	341	1.50	364	2.50	428

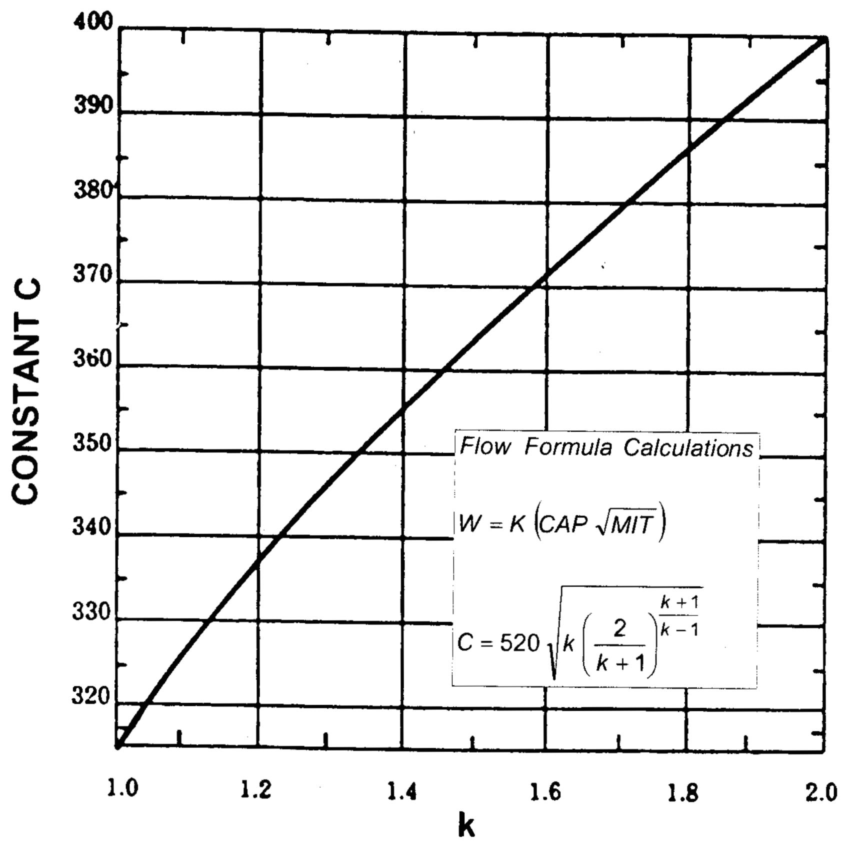


Figure 1—Constant *C* for gas or vapor related to ratio of specific heats ($k = C_p/C_v$) at 60 °F and 14.696 psia

Appendix A—Basis for sizing of pressure relief device (Normative)

NOTE—This form is not suitable for acetylene cylinders. For further information, contact the Compressed Gas Association, Inc., 4221 Walney Rd. 5th Floor, Chantilly, VA 20151.

Date: ______________________

Manufacturer: ______________________

Address: ______________________

Catalog or Model No.: ______________________

Drawing No. ______________________ Date of Dwg. and Latest Revision: ____________

Pressure Relief Device Type CG-______________________ See Table 1 of CGA S-1.1

Set Pressure: ______________________psig Flow Rating Pressure: ____________

Yield Temperature: ______________________°F Rated Bursting Pressure: ____________

Chemical Name of Gas: ______________________

☐ Liquefied ☐ Nonliquefied

Commerical Name of Gas: ______________________

Percentage of Components for Mixed Gases: ______________________

Specification and Service Pressure of DOT Cylinder(s) to be Used______________________

Maximum Container Size for Which Approval is Requested ______________________
(pounds water capacity)

Minimum Required Flow CFM of Air (See CGA S-1.1, Para. 5.2 to 5.4)______________________

Actual Flow CFM of Air at 60 °F and Base Pressure of 14.696 psia______________________
(Item 16 of Test Data)

Test Conducted By:______________________ Title______________________

Company______________________

Signature______________________ Date______________________

Test Requested By:______________________ Title______________________

Company______________________

Signature______________________ Date______________________

NOTE—For pressure relief devices on the insulation jacket of CTC/DOT-4L and TC-4LM cylinders, indicate:

Description of Device ______________ Discharge Area ______________ Set Pressure __________psig

(For Test Data, see next page)

Test Data

This form is suitable for test data using orifice meters.

The medium: Air ______ or name of gas ______________________________

Specific gravity _______

Molecular weight ______ Ratio of specific heats (k)______________________________

	Item	Samples		
		1	2	3
1.	Start-to-discharge pressure (psig)			
2.	Resealing pressure (psig)			
3.	Rupture disk bursting pressure (psig)			
4.	Fusible plug yield temperature (°F)			
5.	Flow rating pressure (psia), (i.e., psig + 14.696)			
6.	Orifice diameter (in)			
7.	Meter pipe inside diameter (in)			
8.	Orifice factor (for flow in CFM) (See Table 5 of CGA S-1.1.)			
9.	Constant (Item 8 x $\sqrt{\text{Item 5}}$)			
10.	Differential pressure $\sqrt{\text{(in of water)}}$			
11.	Flow temperature			
12.	Temperature correction factor (See Table 4 of CGA S-1.1.)			
13.	Compressibility factor (air = 1.0)			
14.	Gas constant ratio (*)			
15.	Flow (Items 9 x 10 x 12 x 13 x 14)			

16. AVERAGE FLOW AT 60 °F AND 14.696 psia: ______________________________

(*) Gas constant ratio for air = 1.0; for other than air = 356/Gas constant (C). See Figure 1.

Appendix B—Requalification procedures for CG-7 pressure relief valves (Normative)

Note shall be taken that not all pressure relief valves (CG-7) are designed to be requalified. For those pressure relief valves that are designed for requalification, the following nine-step procedure shall be followed:

1. The following data shall be recorded: pressure relief valve manufacturer, date of manufacture, minimum start-to-discharge pressure, and flow rating pressure. This data may be on the valve in a coded form and not obvious to the retester. The retester shall therefore have in his possession a copy of the latest pressure relief valve coded markings from the manufacturer(s) of the devices that are being requalified.

***WARNING**: Only trained personnel shall attempt to proceed with this test. When conducting pressure tests, only use inert gases (such as nitrogen) to pressurize the testing manifold. Operators shall use safety glasses and other related safety equipment as deemed necessary. Failure to comply with this warning can result in personal injury or death.*

2. Install the pressure relief valve in a test manifold and immerse the pressure relief valve under water to a maximum of 4 in (102 mm).

3. Pressurize the pressure relief valve to 75% of its flow rating pressure. Observe the pressure relief valve for any bubble discharge. If no discharge is present, go to step 4. If continuous bubble discharge from the pressure relief valve is present, reduce the pressure until the discharge ceases and slowly increase the pressure until the bubble discharge is observed. If the continuous discharge from the pressure relief valve is observed at less than 75% of the flow rating pressure for the pressure relief valve, the pressure relief valve fails the test and shall be removed from service.

4. If no bubbles are noted, increase the pressure in the manifold 50 psig and hold the pressure for 30 seconds. Observe the pressure relief valve for continuous bubble discharge. Continue the test by increasing the pressure in 50 psig increments until continuous bubble discharge is noted or the manifold pressure is equal to the 100% of the flow rating pressure of the pressure relief valve.

   If at any time during the test, as defined above, continuous bubble discharge is noted, record the start-to-discharge pressure of the pressure relief valve and proceed to step 6.

5. If continuous bubble discharge is not noted at 100% of the flow rating pressure of the pressure relief valve, hold the pressure for 5 minutes. Failure to obtain continuous bubble discharge within the 5-minute allotment indicates failure of the pressure relief valve, and the pressure relief valve shall be removed from service.

6. Once continuous bubble discharge has occurred and the pressure recorded, decrease the pressure on the manifold at a rate not exceeding 100 psig per minute. Record the pressure at which the bubble discharge ceases. This is the resealing pressure of the pressure relief valve. Failure of bubble discharge to cease within the requirements as set forth in 4.3.1 indicates failure of the pressure relief valve, and the pressure relief valve shall be removed from service.

7. Discharge all pressure from the manifold and without cleaning, removing parts, or reconditioning, each pressure relief valve shall be subjected to an actual flow test at its flow rating pressure, wherein the amount of air or gas released by the pressure relief valve is measured. Failure to achieve the rated flow capacity results in failure of the test, and the pressure relief valve shall be removed from service. Pressure relief valves passing the flow test will then be retested in accordance with steps 2-6 after at least 1 hour following the flow test. There is no need to perform step 7 a second time. Such a test may be made by the manufacturer of the pressure relief valve or by a qualified test laboratory.

8. If all requirements have been achieved, the pressure relief valve shall be marked to identify the date of requalification and the identity of the company performing the requalification.

9. The records shall be signed and dated by the person performing the requalification. Records of the requalification of pressure relief devices shall be kept for a minimum of 6 years by the company performing the requalification.